Marine Fisheries
REVIEW
Vol. 73, No. 1
2011
United States Department of Commerce

THE MENHADEN BAIT FISHERY

Marine Fisheries REVIEW

W. L. Hobart, Editor
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On the cover: The FV *Marian Leigh* pursed Atlantic menhaden for bait out of Reedville, Virginia, in the early 1990's. Photo: W. Bradley O'Bier.

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The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The annual subscription price is $21.00 domestic, $29.40 foreign. Single copies are $12.00 domestic, $16.80 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

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This publication is available online at http://spo.nwr.noaa.gov/mcontent.htm

The Bait Purse-seine Fishery for Atlantic Menhaden, *Brevoortia tyrannus*, in the Virginia Portion of Chesapeake Bay

JOSEPH W. SMITH and W. BRADLEY O'BIER

Introduction

Atlantic menhaden, *Brevoortia tyrannus*, are estuarine-dependent, marine migratory members of the herring family of fishes (Ahrenholz, 1991). They are of moderate size, with some specimens reaching over 300 mm in fork length and weighing up to 1.0–1.5 kg. Menhaden are ubiquitous, occurring in coastal waters of the U.S. Atlantic coast, and inhabiting most major estuarine systems. Spring through fall, menhaden form large near-surface schools, which are the targets of a large industrial fishery for fish meal, fish oil, and fish solubles (Smith, 1991).

Menhaden flesh is high in protein (Dubrow et al., 1976) and rich in marine oils and fatty acids (Joseph, 1985). Given these qualities and the ubiquitous nature of menhaden schools, it is not surprising that menhaden are a preferred bait for trap or pot fisheries for blue crab (Van Engel, 1962; Warner, 1976), American lobster (The Free Press, 2010), and crawfish (LSU AgCenter, 2008).

The purse-seine reduction fisheries for Atlantic menhaden are well-documented (Nicholson, 1975; Smith, 1991) and stock assessments are conducted regularly as prescribed in the Fishery Management Plan (FMP) for the species (ASMFC, 2001). During the early 1990's, the Atlantic Menhaden Advisory Committee (AMAC) of the Atlantic States Marine Fisheries Commission (ASMFC), which at the time was responsible for reviewing menhaden fishery-dependent data, was concerned that harvests of menhaden for bait were increasing, while landings for major segments of the bait fishery may have been undocumented. Beginning in 1994, the AMAC took steps to improve data collection of menhaden bait landings and age and size composition of the catch.

One substantial facet of the bait fishery that was suspected of under-reported landings was a directed purse-seine fishery for bait which developed during the 1970's among several vessels in the Virginia portion of Chesapeake Bay. These craft were smaller than the vessels in the industrial fishery, with commensurate reductions of gear and crew members. The vessels and their purse-seine gear are colloquially called "snapper rigs" in Tidewater Virginia. The origin of the term is ill-defined, but it probably reflects local slang. Small bluefish, *Pomatomus saltatrix*, are locally referred to as snappers, and some suggest that this scaling vernacular was likewise applied to the menhaden bait gear. One source (Castro et al., 2007) indicates that the term was coincidently adopted for bait vessels and purse-seine gear in Narragansett Bay, R.I. Regardless of the moniker's origin, by an unusual nuance in Virginia fisheries statutes, regulatory authority over the menhaden fisheries in the Old Dominion resides with the legislature in the Commonwealth's capital at Richmond, and not with the Virginia Marine Resources Commission (VMRC) in Newport News, which regulates all other marine fisheries resources. With VMRC lacking statutory authority to collect menhaden data, bait landings by snapper rigs consequently often went unreported.

In 1994 the AMAC formed a Bait Subcommittee to better substantiate menhaden bait landings along the U.S. eastern seaboard. AMAC members from the Beaufort Laboratory of the National Marine Fisheries Service, owing to decades of work with the reduction purse-seine fishery in Chesapeake Bay, were asked to document landings and age and size composition of the catch in Virginia's snapper rig bait fishery. In this report we describe our efforts to improve data collection for the menhaden purse-seine bait fishery in Chesapeake Bay. Herein, we: 1) characterize the bait purse-seine fishery for Atlantic menhaden in Virginia by describing the vessels, gear, and disposition of the catch, 2) describe catch and fishing effort, especially seasonality and areal distribution of the catch, using annual logbook data sets, and 3) describe the age and size composition of the catch through port samples, as well as the disposition of the catch.

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ABSTRACT—Through the mid 1990's, the bait purse-seine fishery for Atlantic menhaden, Brevoortia tyrannus, *in the Virginia portion of Chesapeake Bay was essentially undocumented. Beginning in 1995, captains of Virginia bait vessels maintained deck logs of their daily fishing activities; concurrently, we sampled the bait landings for size and age composition of the catch. Herein, we summarize 15 years (1995–2009) of data from the deck logbooks, including information on total bait landings by purse seine, proportion of fishing to non-fishing days, proportion of purse-seine sets assisted by spotter pilots, nominal fishing effort, median catches, and temporal and areal trends in catch. Age and size composition of the catch are described, as well as vessel and gear characteristics and disposition of the catch.*

NET No.

CAPTAIN'S DAILY FISHING REPORT

NAME OF VESSEL 1	PLANT 2	DATE OF SETS 3	4

LEFT DOCK 5 ANCHORAGE

DATE

TIME

: ❑ AM
: ❑ PM

IF DID NOT LEAVE DOCK (CHECK ONE) 6

- ❑ WEATHER UNFIT FOR FISHING
- ❑ LACKING SUFFICIENT CREW
- ❑ MECHANICAL
- ❑ NET
- ❑ UNLOADING
- ❑ RADIO
- ❑ OTHER _____
- ❑ HOLIDAY

IF NO SETS WERE MADE (CHECK ONE) 7

- ❑ ROUGH SEAS
- ❑ FOGGY
- ❑ NO FISH SHOWING
- ❑ NO PLANES
- ❑ CHANGING LOCATION
- ❑ OTHER _____

8 SET NO.	TIME 9 START	TIME 9 END	10 FISH (000)	11 PLANE NO.	12 LOCATION		13 MILES AND DIRECTION TO SHORE		14 WEATHER CONDITIONS AND REMARKS	15 SEA WATER TEMP.
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

16 REMARKS & COMMENTS 17

DATE/TIME RETURN TO DOCK:

CAPTAIN'S SIGNATURE 18

This form is required by State Law

Figure 1.—A blank Captain's Daily Fishing Report (CDFR) form from the mid 1990's.

Data Collection

Logbooks

At the start of the 1995 fishing season, to better quantify menhaden bait landings in Virginia, we identified and solicited captains of menhaden bait vessels to voluntarily complete daily logbooks of fishing activity called Captain's Daily Fishing Reports, or CDFR's (Fig. 1); these are identical to CDFR's completed by reduction vessels where compliance in Virginia is 100% (Smith, 1999). For each purse-seine set, CDFR's enumerate time of set, an "at-sea" estimate of catch and fishing location, whether an aircraft was used to direct the set, distance from shore, and some weather variables. CDFR's were maintained onboard by vessel crews throughout the fishing season and were collected at season's end.

Between 1995–97 most, but not all, snapper rigs participated in the CDFR program; beginning in 1998 to the present, compliance by Virginia bait vessels has been 100%. In 2001, to ensure future compliance, Amendment 1 of ASMFC's FMP for Atlantic menhaden (ASMFC, 2001) specified mandatory reporting of landings by all menhaden bait purse-seine vessels preferably using CDFR forms. At a minimum, snapper rig captains complete a CDFR form if they make at least one purse-seine set during a given fishing day. Although not required by Amendment 1, some but not all snapper rig captains complete CDFR's for days when no sets are made, noting if they did not leave the dock or, if they left the dock, that they did not make a set on the fishing grounds.

Bait CDFR's were collated, key-entered, edited, and stored as annual data sets at the NMFS Beaufort Laboratory. Summary and statistical analyses were performed using SAS (SAS, 1995) programs. CDFR forms were relatively unaltered through 2004 (Fig. 1). In 2005 data fields were added to capture GPS coordinates of fishing locations; prior

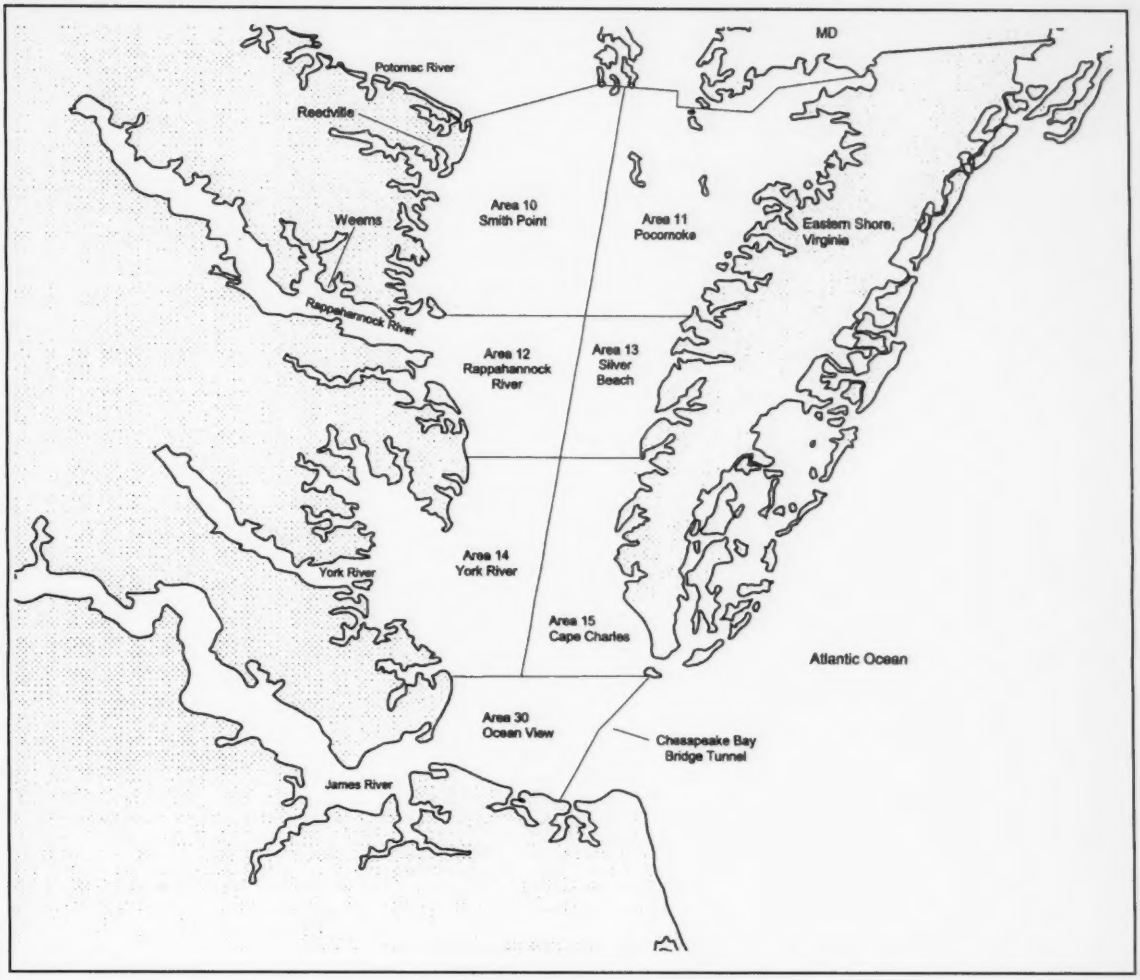

Figure 2.—The Virginia portion of Chesapeake Bay showing "large" reporting areas as defined by the CDFR program.

to this, fishing locations were identified by one of seven large fishing zones in the Virginia portion of Chesapeake Bay (Fig. 2) and by distance from nearest prominent geographic point. In 2009, the form was revamped again (Fig. 3) so that data were optically scanned directly into electronic files, vs. data-capture via the time-consuming key-entry process.

Port Samples

Beginning in 1995, the menhaden port agent at Reedville, Va., was directed to acquire dockside samples of Atlantic menhaden from bait vessels, all of which operate from the Northern Neck region, near the menhaden reduction factory at Reedville. Sampling intensity, or target number of bait port samples for a fishing season, was about 40, based on a historical proportion of samples to landings in the reduction fishery.

Biological sampling of the bait fishery is similar to that of the reduction fishery and is based on a two-stage cluster design (Chester, 1984). The port agent randomly selects the bait vessels, and at dockside retrieves a bucket of fish (first cluster) from the top of the vessel's fish hold. The sample is assumed to represent fish from the last purse-seine set of the day, not the entire boat load or trip. The agent ascertains from the crew the location and date of the last set. From the bucket the agent randomly selects ten fish (second cluster), which are measured (fork length in mm), weighed (grams), and some scales are removed for aging. June and Roithmayr (1960) performed detailed examinations (validation and verification) of Atlantic menhaden scales and determined that rings on the scales are reliable age marks.

CAPTAIN'S DAILY FISHING REPORT

Net Number:

VESSEL NAME: OSPREY
DATE: 8 / 7 / 09 (month / day / year)
OFFICE USE ONLY — VESSEL NUMBER: 23
PLANT: REEDVILLE
PLANT NUMBER: 44

IF VESSEL DID NOT LEAVE THE DOCK ON THIS FISHING DAY, CHECK HERE

IF VESSEL LEFT THE DOCK AND DID NOT MAKE ANY SETS ON THE FISHING GROUNDS THIS FISHING DAY, CHECK HERE

SET NO.	TIME (Military) START	TIME (Military) END	FISH (000)	PLANE NO.	FISHING LOCATION CDFR 5-DIGIT CODE	FISHING LOCATION GPS (dd °, mm ', ss ")(degrees, minutes, decimal seconds) LATITUDE	FISHING LOCATION GPS (dd °, mm ', ss ")(degrees, minutes, decimal seconds) LONGITUDE	MILES TO SHORE	WEATHER CONDITIONS Cloud Cover	Air Temp.	Wind Dir.	Wind Speed
1	1050	1150	40	1	11060	37 38 32	76 01 51	54	3	78	2	12
2	1230	1315	30	1	11060	37 39 18	75 58 17	40	3	78	2	11
3	1340	1430	45	1	11060	37 37 69	76 00 82	47	3	79	2	10
4	1445	1525	35	1	11060	37 38 74	76 02 41	63	3	80	2	10
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

PUMP OUT

COMMENTS:

DATE / TIME RETURN TO DOCK 1730 hrs. 8/7/09

CDFR CREATED: 02/17/2009 Rev. 010

Figure 3.—A completed CDFR from a Virginia snapper vessel from the 2009 fishing season.

Description of Virginia's Bait Purse-Seine Fishery for Atlantic Menhaden

Vessels

During 1995–2009, a total of eight vessels participated in the bait purse-seine fishery in Northern Neck. Up to five vessels fished during 1999–2000, four during 2001–05, three during 2006–08, and four in 2009; only one vessel fished continuously through the entire time period. All but one or two of the vessels fished from the port of Reedville (Cockrell's Creek) near Smith Point at the mouth of the Potomac River (Fig. 2); landings also occurred near Weems along the north shore of the lower Rappahannock River.

Of the five vessels active in the bait fishery over the past 5 years, three were built for the menhaden reduction fishery. The *Taylor's Creek* (Fig. 4) and *Hushpuppy* (Fig. 5) originally fished on menhaden for reduction at Beaufort, N.C. They were "sound boats" making day-trips to fish in central North Carolina's coastal sounds and bays. The *Hushpuppy* was sold to a bait concern in Northern Neck in about 1988; the *Taylor's Creek* moved to Virginia in 1998. The *Carter's Creek* (Fig. 6) was originally the *Absecon* and fished in the reduction fishery during the 1950's and 1960's. In about 1978 she was converted to a clam dredger for the surf clam, *Spisula solidissima*, and ocean quohog, *Artica islandica*, fishery in the mid Atlantic, and also fished as a trawler for horseshoe crabs, *Limulus polyphemus*. She was retrofitted again in 2005 to purse seine menhaden for bait.

The *Osprey* (Fig. 7) was originally built as a shrimp trawler for the southeast U.S. coast, and was converted to a menhaden vessel in about 1996. The *Indian Creek* (Fig. 8) was a former military tugboat, and it was converted to a bait purse-seiner for the 2009 fishery. Four of the five vessels in the fishery during the past 5 years are less than 100 ft long. In the parlance of the menhaden fishery, maximum hold capacities of the

Table 1.—First and last fishing days of Virginia's menhaden "snapper rig" bait fishery, 1995–2009.

Year	First fishing day	Last fishing day
1995	May 4	Nov. 13
1996	May 20	Nov. 13
1997	May 5	Nov. 11
1998	May 6	Nov. 9
1999	May 7	Nov. 10
2000	May 1	Nov. 8
2001	May 8	Nov. 14
2002	May 6	Nov. 2
2003	May 20	Nov. 17
2004	May 6	Nov. 2
2005	May 2	Nov. 15
2006	May 9	Nov. 15
2007	May 11	Nov. 12
2008	May 5	Nov. 11
2009	May 11	Nov. 10

four extant bait vessels in 2009 ranged from 250,000 to 550,000 "standard fish" (1,000 "standard fish" = 670 lb), or about 76–167 t. Snapper rig vessels have refrigerated fish holds; chilled seawater is sprayed atop the catch via baffles and recirculated through drains in the bottom of the hold.

Gear

Standard mesh size (bar length) for purse-seine gear in Chesapeake Bay is 7/8-in, which is the minimum allowed by Virginia law. During the initial decades of the snapper rig fishery, purse seines for bait were scaled-down versions of the larger nets used in the menhaden reduction fishery (which often approach 1,200 ft long and 80–90 ft deep). Bait purse seines are usually acquired as surplus nets from the reduction fishery; the bag or bunt section is moved from the middle of the net to the end, then tapered to accommodate the single purse boat method of setting the seine. As the bait fishery has evolved, dimensions of snapper rig nets now rival reduction nets in length and depth. Snapper rigs normally utilize one purse boat to set the net and employ 6 or 7 crew members, as well as a spotter pilot to locate schools of menhaden.

Fishing Season

The menhaden purse-seine fishing season in Chesapeake Bay extends from the first Monday in May through the third Friday in November, regardless of the disposition of the catch. By choice, fishing is almost exclusively done during weekdays. Purse-seine fishing is mostly restricted to lower Chesapeake Bay proper, and is prohibited in most tributaries of the bay, except for the lower reaches of the Rappahannock and York rivers. One exception allows vessels under 70 gross tons (ostensibly bait vessels, but none in the extant snapper rig fleet qualify) to fish in a few additional tributaries of Northern Neck during the purse-seine season.

CDFR information revealed that during 1995–2009, initial purse-seine sets for bait were made in early to mid May (Table 1); average date-of-first-set was 8 May. Final purse-seine sets for bait were made in early to mid November (Table 1); average date-of-last-set

Figure 4.—*F/V Taylor's Creek*, 87-ft long, began her career in Beaufort, N.C., as a purse-seiner for the reduction fishery. She moved to Northern Neck, Va., and began fishing with the "snapper rig" fleet in 1998. Photo credit: WBO.

Figure 5.—*F/V Hushpuppy* is an 81-ft steel-hulled vessel. For comparative purposes, here she is in the foreground with the *F/V Gregory Poole* in the background, an 176-ft vessel in the reduction purse-seine fleet. *F/V Hushpuppy* began service as a menhaden purse-seiner for the reduction fishery in Beaufort, N.C. She was sold to a menhaden bait firm in Northern Neck, Va., in 1988. Of extant bait vessels in Va., *F/V Hushpuppy* has had the longest continuous service. Photo credit: JWS.

was 11 November. Assuming these mean start and finish dates, an average fishing season in the bait fishery extends about 27 weeks and consists of approximately 135 "weekday" fishing days.

Total Annual Landings

Because VMRC has no mandate to collect menhaden fishery statistics, bait landings in Virginia prior to about 1995 are somewhat suspect and may be underestimates, especially those from the snapper rig vessels. To better document landings we placed CDFR's onboard two of four bait vessels in 1995 and on two of three vessels in 1996 and 1997. From 1998 to present, all snapper rig vessels maintained CDFR's (Table 2).

Since daily trip tickets or reasonable facsimiles are not required of snapper rig vessels in Virginia, dockside measures of bait landings are unavailable. Nevertheless, summed at-sea estimates of daily purse-seine catches from CDFR's are considered reliable estimates of total daily catch because menhaden captains are particularly adept at estimating individual purse-seine catches. For example, Smith (1999) showed that for menhaden reduction vessels in Virginia, vessel-specific ratios of actual annual landings to annual CDFR estimates of catch ranged from 0.90 to 1.03 for the 20-vessel fleet in 1995. Thus, CDFR estimates of catch for the snapper rig fleet are considered reasonably accurate estimates of landings. CDFR catch estimates are couched in the vernacular of the menhaden industry, that is, in thousands of "standard fish," which were multiplied by 0.3039 to convert to metric tons (Smith, 1991).

Figure 6.—*F/V Carter's Creek* is an 135-ft vessel which unloads Atlantic menhaden at Reedville, Va., for both bait and reduction. She began her service as a menhaden reduction vessel in the late 1950's, was converted to participate in various dredge and trawl fisheries in the 1970's, then was converted back to a menhaden purse-seiner in 2005. Photo credit: JWS.

During the 1980's menhaden bait landings by snapper rigs were largely undocumented, but they were probably equivalent to Virginia's menhaden bait landings by all other fishing gears (mostly pound nets, gill nets, and haul seines) (Table 3). By the late 1990's menhaden bait landings by snapper rigs were five times greater than those of other gears combined. This contrast continues through present, and was most disparate in 2003 when landings by snapper rigs amounted to 20,879 t and bait by all other gears totaled 1,584 t.

Snapper rig landings for bait during 1989–92 were poorly documented, but averaged about 5,000 t annually (Table 3), probably from two or three active vessels. Beginning in the mid 1990's, landings increased and more than doubled to 11,190 t by 1995, then climbed to 17,640 t by 1998, most probably a reflection of more accurate data collection via the CDFR's. Landings declined to 12,763 t in 2000, then increased again over the next 3 years, peaking for the time series at 20,879 t in 2003. Landings in 2005 of 19,814 t rivaled those of 2003, however, landings in 2004 fell to 9,361 t, less than half of the previous year's total. By 2008, landings improved again to 13,213 t. Landings during 2007–09 averaged 12,799 t.

Snapper rig landings in Virginia contribute substantially to coastwide landings of Atlantic menhaden for bait

Figure 7.—*F/V Osprey*, 90-ft long, is a converted shrimp trawler. She began service as a purse-seiner for bait at Reedville, Va., in about 1996. Photo credit: JWS.

(Table 3). During the 1990's, Virginia's snapper rig landings as a proportion of total coastwide landings of menhaden for bait grew from 11% in 1991 to 45% in 1998. No doubt much of this increase was because of better documentation of snapper rig landings. By 2003 snapper rig landings represented 62% of coastwide menhaden bait landings, although in recent years this percentage has declined to roughly 30%.

Figure 8.—*F/V Indian Creek* is one of the newest entrants (2009) to Virginia's "snapper rig" fleet. She is a converted military tug boat. Photo credit: JWS.

Table 2.—Virginia menhaden "snapper rig" fleet: Number of vessels, CDFR's, days with at least one set, number of sets, median catch, sets/day/vessel, and percent of spotter pilot-assisted sets during 1998–2009.

Year	Vessels reporting	No. of CDFR's	Days with ≥1 set	Total no. of sets	Median catch (t) for all vessels	Sets/vessel/day		Spotter assisted sets (%)
						Median	Max	
1998	5	327	271	1,016	11	3	10	95
1999	5	438	345	1,420	9	4	10	92
2000	5	402	270	1,084	11	3	8	93
2001	4	384	341	1,242	12	3	9	93
2002	4	399	360	1,423	11	4	9	99
2003	4	399	337	1,195	15	3	10	92
2004	4	466	345	1,303	12	3	10	90
2005	4	482	369	1,399	12	3	8	96
2006	4	369	235	799	11	3	8	92
2007	3	318	258	860	12	3	8	97
2008	3	319	251	857	14	3	8	99
2009	4	340	247	860	12	3	9	99

CDFR Compliance, Spotter Pilot Activity, and Fishing Days

Beginning in 1998 to the present, compliance for completing CDFR forms by snapper rig captains has been 100%, and captains provided between 318 and 482 CDFR forms annually (Table 2). Snapper rig captains utilized spotter pilots to assist them in locating fish schools and to direct setting the net for over 90% of the sets annually (Table 2). Captains of reduction vessels tend to use spotter pilots less frequently (83% of sets in the Atlantic fleet (Smith, 1999) and about 69% of sets in the Gulf fleet (Smith et al., 2002)), possibly because the larger and taller reduction vessels offer a higher vantage point to "self locate" fish schools.

Some, but not all, snapper rig captains completed CDFR's even on days when they did not fish, noting if they did not leave the dock, or that they went to sea but did not set; hence, one completed CDFR form may not equal a "trip" with sets. During 1995 to 2009 snapper rig vessels fished on average 69.2% (range: 58.1–82.7%) of the available fishing days (almost exclusively weekdays), while not leaving the dock 12.2% of available days, or not setting the net at sea on the remaining 18.6% of days. Assuming a hypothetical 135-day fishing "season" (weekdays) from early May through mid November, snapper rig vessels set on menhaden schools on about 94 (69.2%) of the available fishing days; they stayed at the dock about 16 days (12.2%) and did not set at sea on 25 days (18.6%). These estimates are comparable to the Atlantic menhaden reduction fleet which set on fish 67–83% of available fishing days (Smith, 1999), and the Gulf menhaden reduction fleet which set on fish 63–76% of the available fishing days (Smith et al., 2002).

Description of the Catch, Fishing Effort, and Disposition of the Catch

Nominal Fishing Effort, Median Catch, and Frequency Distribution of Catch

Nominal fishing effort, as reflected by number of purse-seine sets made by snapper rig vessels, ranged from 799 (2006) to 1,423 (2002) annually (Table 2). Median number of sets for bait per vessel per day was 3 or 4 sets (Table 2), which is about one less per day than vessels in the Atlantic and Gulf menhaden reduction fleets (Smith, 1999; Smith et al., 2002). Median catch size for bait ranged from 9 t (1999) to 15 t (2003) (Table 2); this is roughly half of median catch size in the Atlantic menhaden (15–30 t; Smith, 1999) and gulf menhaden (17–22 t; Smith et al., 2002) reduction fisheries. Catch-per-unit-effort for the snapper rig fleet during 1998–2009, as measured by total annual catch in metric tons divided by annual number of purse-seine sets, ranged 12–18 t/set. By comparison, CPUE's for sets by the purse-seine reduction fleet within Chesapeake Bay for the same period ranged from 22 to 31 t/set.[1]

The frequencies of catches per set by 10 t bins were calculated annually, then each bin was averaged over the 12-yr time series (1998–2009) (Table 4). Results indicated that on average 46% of sets were represented in the 0–10 t bin, while 88% of catches were represented in the first three catch intervals, that is, the 0–10, 11–20, and 21–30 t bins. By

[1] Unpublished data on file at NMFS Beaufort Laboratory.

comparison, for the Atlantic menhaden reduction fishery in Chesapeake Bay about 30% of the sets accumulated in the 0–10 t interval, and about 80% of the catch occurred in the 0–10, 11–20, and 21–30 t bins (Smith, 1999).

Set Duration and Hour of Peak Catch

Average set duration, as measured by the time when the purse boat began setting the net until the time when the entire catch was pumped into the fish hold, varied narrowly over the period. Mean set time ranged from 36 to 47 min, and averaged 39 min over the entire time series; these values are equivalent to set times in the Atlantic menhaden reduction fishery (34–43 min; Smith, 1999), and slightly less than set times in the Gulf menhaden reduction fishery (41–48 min; Smith et al., 2002). On average, sets just after sunrise produced the best catches. Hourly mean catches were highest between 0600–0759 hr for 10 of the 12 analysis years (1998–2009).

Table 3.—Virginia landings in metric tons of Atlantic menhaden for bait by "snapper rigs," all other gears, and state totals, as well as coastwide Atlantic menhaden for bait landings, 1981–2009.

Year	Virginia menhaden catch by "snapper rigs" (% of coastwide landings for bait)	Virginia menhaden catch for bait, all other gears	Total Virginia menhaden catch for bait	Total[1] Atlantic coast menhaden catch for bait
1981	4,405	9,734	14,139	
1982		9,988	9,988	
1983		11,105	11,105	
1984		6,589	6,589	
1985		7,856	7,856	26,659
1986		4,484	4,484	27,961
1987		6,495	6,495	30,616
1988		5,433	5,433	36,237
1989	5,778 (19)	5,249	11,027	30,948
1990	5,495 (18)	2,772	8,266	30,685
1991	3,906 (11)	2,665	6,571	36,224
1992	5,065 (13)	2,299	7,364	38,721
1993	8,019 (19)	3,257	11,276	41,889
1994	10,978 (29)	2,570	13,547	37,369
1995	11,190 (26)	2,792	13,982	42,525
1996	11,994 (33)	2,449	14,443	36,735
1997	10,590 (26)	2,396	12,985	41,451
1998	17,640 (45)	1,809	19,449	39,194
1999	15,521 (43)	2,276	17,797	36,094
2000	12,763 (36)	2,861	15,624	35,050
2001	17,464 (48)	1,960	19,424	36,312
2002	18,957 (51)	1,762	20,719	36,834
2003	20,879 (62)	1,584	22,463	33,880
2004	17,740 (50)	2,802	20,542	35,515
2005	19,814 (51)	2,320	22,134	38,832
2006	9,361 (36)	1,693	11,054	26,311
2007	12,445 (29)	3,759	16,204	42,668
2008	13,213 (28)	3,254	16,467	46,674
2009[2]	12,740 (33)	2,507	15,247	38,976

[1]Source: ASMFC (2010) for data through 2008.
[2]Data are preliminary.

Temporal and Areal Trends in Bait Catches

To discern seasonality of the bait catch, annual catches were summed by month, then averaged across fishing years 1998–2009 (Table 5). Peak removals occurred in August (3,401 t) and accounted for 22% of the annual harvest. Catches in July (3,089 t) closely followed those of August and represented 20% of the annual removals. Catches in June (2,469 t; 16%), September (2,321 t; 15%), and October (2,275 t; 15%) were similar and combined comprised 46% of the annual harvest. Catches in May (1,462 t) represented 9% of the total removals; however, on given years when presumably spring weather was fair and fish were abundant, removals in May (2005 when 2,539 t were caught) rivaled mean catches for June and July. Catches in November (418 t) amounted to only 3% of the total removals for the fishing season.

The CDFR Program for the reduction fishery was originally designed in the late 1970's as a joint state, Federal, and menhaden industry effort to provide better information on menhaden catch locations and fishing effort (Smith, 1999). The program obviously predates GPS navigation systems, as well as later versions of LORAN; nevertheless, GPS coordinates for purse-seine sets have been available since 2005.

For pre 2005 catch locations, program designers found it convenient to use a combination line-of-sight locales (tied to nearest geographic points) and distance-from-shore estimates. A catalog of fishing locations was adapted from a menhaden processor at Reedville (Standard Products of Virginia[2]). Individual

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 4.—Frequency distribution of sets for Atlantic menhaden by Virginia "snapper rig" vessels by 10 t bins (bins are defined by their midpoints) averaged over 12 years, 1998–2009.

Bin midpoint (t/set)	Mean no. of sets	Cumulative no. of sets	Cumulative %
5	521	521	46
15	343	864	77
25	123	987	88
35	85	1,072	96
45	24	1,096	98
55	13	1,109	99
65	9	1,118	99
75	2	1,120	99
≥85	1	1,121	100

Table 5.—Virginia "snapper rig" vessels: Mean catch by month averaged over 12 years, 1998–2009, with percent and minimum and maximum values.

Month	Mean catch (t)	Percent of annual mean catch	Minimum catch (t)	Maximum catch (t)
May	1,462	9	803	2,539
June	2,469	16	1,311	3,660
July	3,089	20	1,916	4,025
Aug.	3,401	22	1,580	5,499
Sept.	2,321	15	1,186	3,553
Oct.	2,275	15	1,181	3,870
Nov.	418	3	17	849

fishing locations were subsumed into a larger grid of seven areas in the Virginia portion of Chesapeake Bay (Fig. 2). These areas have proven useful for describing trends of reduction catches in the bay (Smith, 1999) and are also used here.

For summary purposes lower Chesapeake Bay is divided into seven areas; a line running roughly from north to south at the center of the bay separates three paired east-west areas, and one area encompasses the southernmost portion of Virginia's Tidewater region (Fig. 2). Smith Point and Rappahannock River areas on the bay's western shore are nearest to the ports where snapper rig vessels are located, while the Pocomoke area is nearest along the eastern shore of the bay.

Annual catches in Chesapeake Bay were summed by fishing area, and then averaged across fishing years 1998–2009 (Table 6). A majority of catches over the time series occurred in the Smith Point area, the area closest to Reedville and the home port for most of the snapper rig fleet. Annual removals from this area averaged 9,564 t, and represented 62% of the annual catch.

The Rappahannock River area ranked second in terms of annual removals with an annual catch of 2,719 t, representing 18% of the harvest. The Pocomoke area ranked a close third where annual catch averaged 2,575 t, or 17% of the total catch. The Smith Point, Pocomoke, and Rappahannock River areas combined accounted for 97% of the bait removals by snapper rigs from the bay.

By comparison, these three areas accounted for 59% of the removals in Chesapeake Bay by the reduction fleet (Smith, 1999), which is composed of larger vessels that range farther and for longer periods of time in Chesapeake Bay and ocean waters than the snapper rig fleet. Snapper vessels rarely set beyond Chesapeake Bay because ocean waters are often too rough for the smaller bait boats, and because of the distance to the bay mouth (3–4 hr one way). A few sets along the ocean beaches of Virginia's Eastern Shore barrier islands in 2006 were an exception.

Table 6.—Virginia "snapper rig" vessels: Mean catch by fishing area averaged over 12 years, 1998–2009, with percent, minimum, and maximum values.

Area	Mean catch (t)	% of annual mean catch	Minimum catch (t)	Maximum catch (t)
Smith Point	9,564	62	6,593	13,518
Pocomoke	2,575	17	593	4,630
Rappahannock River	2,719	18	359	4,566
Silver Beach	331	2	0	1,655
York River	50	<1	0	258
Cape Charles	170	1	0	579
Ocean View	26	<1	0	202

Table 7.—Percent age composition of Atlantic menhaden in the Virginia bait purse-seine catch by year, 1995–2009.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Total no. sampled
1995	0	35.4	35.4	27.1	2.1	0	0	96
1996	0	0.0	76.6	19.7	3.7	0	0	137
1997	0	9.6	44.8	34.6	8.8	1.5	0.7	136
1998	0	5.3	52.5	27.7	12.8	1.4	0.3	282
1999	0	4.0	72.2	17.7	5.4	0.7	0	299
2000	0.9	23.8	63.2	12.1	0	0	0	231
2001	0.4	4.4	68.0	25.5	1.4	0.3	0	275
2002	0	1.3	20.4	55.5	20.4	2.4	0	470
2003	0.6	9.4	75.4	13.3	1.3	0	0	309
2004	0	6.4	73.6	16.6	3.1	0.3	0	326
2005	0	0.6	51.9	44.7	2.5	0.3	0	318
2006	0	29.5	47.3	20.7	2.5	0	0	203
2007	0	27.5	68.7	2.7	1.1	0	0	374
2008	0	3.5	86.9	7.9	1.3	0.3	0	314
2009	0.2	27	39.3	30.4	3.1	0	0	481
Mean	0.1	12.5	58.4	23.7	4.6	0.5	0.1	

CDFR's also document menhaden for bait catches by distance from the shoreline. Annual catches by snapper rig vessels were summed by distance intervals from shore, then averaged across all fishing years. Catches in the fishing stratum >3.0 mi from shore dominated (43%) annual catches of Atlantic menhaden for bait, followed by the stratum 2.1–3 mi from shore (22%). The near-shore strata, ≤1 mi (17%) and 1.1–2 mi (18%) from shore were nearly equivalent and combined represent 35% of the catch by distance from shore. A similar trend was observed in the reduction fishery for menhaden as 47% of the catch occurred beyond three miles from shore in Chesapeake Bay (Smith, 1999).

Since 2005, captains of snapper rig vessels have provided GPS coordinates of their purse-seine set location on CDFR forms. Locations of individual purse-seine sets for bait and the corresponding catch magnitudes for 2005, which are typical of 2006–09 also, are shown in Figure 9. Obviously, catches and effort are concentrated in the upper half of the Virginia portion of Chesapeake Bay.

Age and Size Composition of the Catch

Port samples acquired from menhaden bait purse-seine vessels in Chesapeake Bay over the 15-yr time series (1995–2009) revealed up to seven age classes in the catch, although only three of these were of major importance to the fishery (Table 7). Age-2 fish predominated in the catch, and on average accounted for 58.4% of the catch. Age-3 menhaden (23.7%) ranked a distant second in terms of numbers in the bait catch, although on one rare occasion (2002) they comprised a majority (55.5%) of the catch. Age-1 fish (12.5%) ranked third in importance, yet during given years they comprised up to 30–35% of the catch. Overall, age-1, -2, and -3 Atlantic menhaden accounted for almost 95% of the snapper rig catch. Mean fork lengths (mm) and weights (g) of Atlantic menhaden in the bait landings by year and age are shown in Tables 8 and 9, respectively.

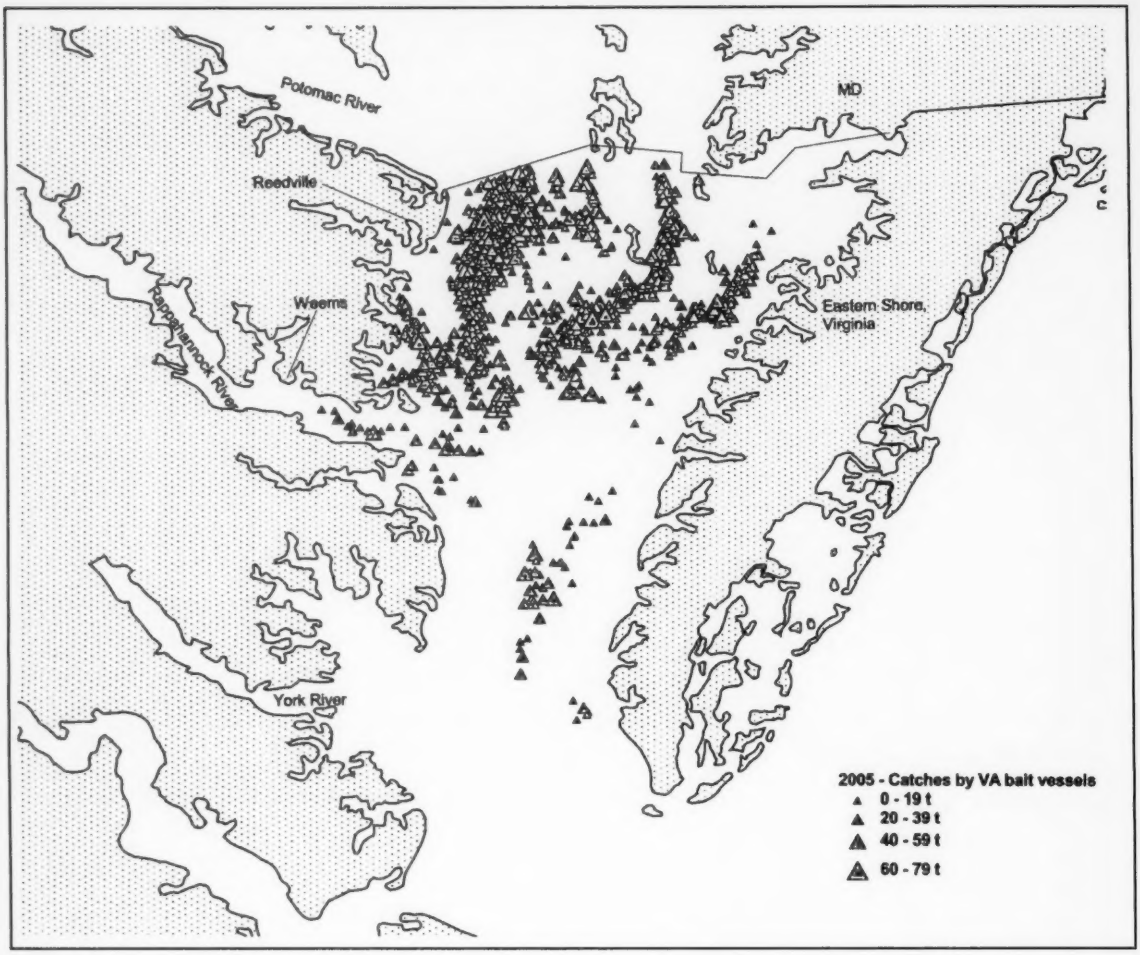

Figure 9.—Locations and magnitude of catches by the Virginia snapper rig fleet during 2005.

Similarly, the age composition of the catch of the reduction fishery (1995–2009)[3] is also comprised of age-0 through age-6 Atlantic menhaden, with mean catch over the period dominated by age-1 (20.4%) and age-2 (61.1%) categories. However, the bait fishery in Chesapeake Bay tends to harvest a slightly greater proportion of older, and presumably larger, menhaden; for example, the proportion of age-3 and age-4 fish in the bait fishery averaged 23.7% and 4.6%, respectively, whereas the same age classes in the reduction fishery averaged 15.1% and 2.5%, respectively.

[3] Unpublished data on file at NMFS Beaufort Laboratory.

Markets for Menhaden as Bait

We interviewed several wholesalers of menhaden for bait in Tidewater Virginia concerning outlets for their product. A consensus of responses indicated that a majority of menhaden landed for bait in Virginia is sold to blue crab pot fishermen in Virginia, Maryland, and the Carolinas. Smaller amounts are shipped to the U.S. Gulf coast for blue crab bait and seasonally for crawfish, *Procambarus clarkia*, bait. Minor amounts of menhaden bait from Virginia are sold in New England for lobster bait; lobster fishermen in New England prefer larger individual menhaden for their bait wells or bags; larger and older Atlantic menhaden are more readily available to bait fishing operations in New Jersey.

Limited amounts of menhaden landed for bait in Virginia are sold to sport fishermen for cut bait or chum; small quantities are also ground into a frozen chum product and marketed to anglers. When bait markets are "soft," that is,

the markets are glutted with landings, or when menhaden in the catch are too small for the bait markets, snapper rig vessels will unload their catch at the menhaden factory in Reedville where it is reduced to fish meal and fish oil.

Bait dealers in Virginia blast freeze menhaden, then pack frozen fish in 50-lb cardboard flats. Fresh menhaden for bait is also sold in 65-lb bushel baskets. The practice of packing menhaden for bait in 100-lb wooden crates, or "fish boxes," has fallen from favor and is a rarity among contemporary bait wholesalers in Virginia.

Summary and Epilogue

Over the past 4 decades, the menhaden snapper rig fishery in the Virginia portion of Chesapeake Bay has become a major contributor to the bait landings on the U.S. East coast, and on given years represented over 50% of coastwide menhaden landings for bait. Menhaden landings by snapper rigs in Virginia are widely distributed to bait markets for blue crab fisheries in Chesapeake Bay, the Carolinas, and the U.S. Gulf coast. New vessels entering into the fishery in recent years attest to its vitality.

Recent bait-related management decisions in New England and New Jersey could have significant near-term implications for Virginia's snapper-rig fishery. Atlantic herring, *Clupea harengus harengus*, is one of the preferred baits for lobster pots in New England. For fishing years 2010–12, the New England Fishery Management Council (NEFMC) proposed reducing annual Atlantic herring catch quotas to about 106,000 t, down from about 194,000 t in 2009 (Federal Register, 2010). By some estimates (The Free Press, 2010) in 2010 the state of Maine alone would need to import 20,000 t of menhaden for lobster bait to offset the shortfall in herring bait.

In a related event in 2010, New Jersey moved to limit entry into its purse-seine fishery for bait (Cape May County Herald, 2010), fearing an influx of bait vessels from New England into Garden State waters. While heretofore only minor amounts of bait from Virginia reportedly enter New England bait markets, recent actions by the NEFMC and New Jersey suggest that landings of menhaden for bait in Virginia could become an even more important facet of bait landings for the U.S. East coast in the near future.

Table 8.—Mean fork length (mm) of Atlantic menhaden in the Virginia bait purse-seine catch by age and year, 1995–2009.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
1995		178	244	271	290		
1996			259	291	300		
1997		179	247	276	296	302	313
1998		158	233	285	308	317	317
1999		201	225	270	291	310	
2000	144	193	257	276			
2001	150	173	260	291	323	312	
2002		189	247	278	288	271	
2003	148	220	243	286	311		
2004		191	233	261	295	297	
2005		210	253	278	291	299	
2006		202	242	274	300		
2007		189	225	274	289		
2008		205	240	259	290	300	
2009	152	193	238	268	279		
Mean	149	192	243	276	297	301	315

Table 9.—Mean weight (g) of Atlantic menhaden in the Virginia bait purse-seine catch by age and year, 1995–2009.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
1995		92	252	335	417		
1996			317	445	464		
1997		108	270	370	463	472	531
1998		70	237	431	553	558	579
1999		142	199	343	430	519	
2000	49	136	300	362			
2001	59	93	309	429	573	564	
2002		129	274	380	429	333	
2003	56	223	281	469	593		
2004		128	221	317	434	410	
2005		154	279	360	402	453	
2006		142	245	341	468		
2007		115	191	319	358		
2008		152	233	290	399	421	
2009	60	122	227	311	339		
Mean	56	129	256	367	452	466	555

Acknowledgments

We wish to thank the captains of Virginia's snapper rig fleet for assiduously completing CDFR logbook forms beginning in the mid 1990's, even before compliance was made mandatory in 2001. Many individuals harvesting and handling menhaden for bait shared their knowledge of the bait fishery, especially Captains Fredrick Rodgers and Jimmy Kellum, and also Margaret Bevans Ransome of Bevans Oyster Co. At the NMFS Beaufort Laboratory, Ethel Hall "aged" port samples from the bait fishery, and James Waters, Michael Burton, and Patti Marraro reviewed initial drafts of the manuscript. Peter Himchak, Brandon Muffley, and Jeff Brust of the New Jersey Division of Fish and Wildlife compiled annual coastwide landings of menhaden for bait.

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Census of Active Commercial Fishermen in Puerto Rico: 2008

DANIEL MATOS-CARABALLO and JUAN J. AGAR

Introduction

Tropical fisheries have long provided sustenance, income, and employment to many coastal communities in the Commonwealth of Puerto Rico (Griffith and Valdés-Pizzini, 2002; Griffith et al., 2007; Agar et al., 2008). However, the declining health of many fish stocks and the ensuing impacts on coastal communities prompted the overhaul of the existing management regime (Matos-Caraballo et al., 2005; Matos-Caraballo et al., 2008; Matos-Caraballo, 2009). Many reef fish species, particularly snapper (Lutjanidae) and grouper (Serranidae) stocks, are vulnerable to overexploitation because of their slow growth, late sexual maturity, sedentary behavior, and predictable aggregated spawning events (Sadovy and Eklund, 1999).

On 11 March 2004, Puerto Rican Regulation No. 6768 brought about sweeping changes in the way local fisheries were managed, including mandatory licensing and landings reporting requirements, which had been voluntary since 1931, and stringent conservation measures (DRNA, 2004; Matos-Caraballo, 2009). Among the controversial management measures were the establishment of commercial license tiers tied to income reporting requirements, additional closed seasons for red hind, *Epinephelus guttatus*, and mutton snapper, *L. analis*; and new minimum size restrictions for commercially valuable species such as silk snapper, *L. vivanus*; yellowtail snapper, *Ocyurus chrysurus*; blackfin snapper, *L. buccanella;* and queen conch, *Strombus gigas*. Additionally, the new rules mandated the purchase of permits for harvesting queen conch, spiny lobster, *Panulirus argus*; land crab, *Cardisoma guanhumi*; sirajo gobies, *Sicydium plumiere*; and miscellaneous by-catch species, and closed the Nassau grouper, *E. striatus*, and goliath grouper, *E. itajara*, fisheries, which had been closed in Federal waters since the early 1990's (Matos-Caraballo, 1997; Matos-Caraballo, 2009). The regulation also prohibited, after a three-year waiting period, the use of beach seines to protect juvenile fish. Notwithstanding these changes, Commonwealth fisheries remained under a regulated open-access regime.

In spite of the Commonwealth's best intentions to rebuild and conserve local stocks, these regulations generated considerable hostility towards local fishery managers. Hundreds of fishermen ceased reporting their landings statistics and refused to participate in the biostatistical sampling program.[1] Ceasing to

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[1] The biostatistical sampling program is responsible for collecting size frequency data and age at length data from commercial landings.

ABSTRACT—The implementation of Puerto Rican Regulation No. 6768, which overhauled the existing fishery management framework, generated considerable hostility towards local managers. Among the controversial management measures adopted in 2004 were the assignment of fishing licenses based on fishing income, the establishment of closed seasons, and new minimum size restrictions for commercially valuable species. Though tensions have subsided, considerable opposition to these regulations remains. This paper provides a characterization of the current population of active small-scale fishermen, discusses their perceptions about the biological and socio-economic condition of the fishery, and describes their attitudes towards the new management framework.

This study revealed that the number of active fishermen decreased from 1,731 in 1988 to 868 in 2008. Although a declining resource base was one of the main drivers behind these waning participation statistics, rising fuel costs and burdensome regulations exacerbated the rate of attrition. The majority of the fishermen were middle-aged men (50 years) with moderate levels of formal education and high levels of fishing dependence which limited their employment opportunities outside the fishery. Most of the vessels were small (20 ft) and outfitted with a single outboard engine (80 hp). Hook and line and SCUBA were dominant gears because of their versatility and cost effectiveness. Fishermen suggested that their opposition to the regulations would continue unless they were afforded greater regulatory flexibility and provided with a larger role in the decision-making process. Fishermen were adamant about the need to reconsider the income reporting requirements to secure a fishing license because of the potential for losing public assistance benefits. They also objected to increasing the minimum size of many deepwater snapper (Lutjanidae) and grouper (Serranidae) species because it forced them to discard dead fish, a practice they consider wasteful since these species do not survive the ascent to the surface once hooked.

report or misreporting of landings is a common method of resistance used to repudiate management actions that are perceived to be heavy handed or unfair (Scott, 1987; Garcia-Quijano, 2009). Though resentment began to subside in 2006, the resolution of the conflict remains problematic. This paper provides a characterization of the current population of active small-scale fishermen, discusses their perceptions about the biological and socio-economic condition of the fishery, and describes their attitudes towards the new management framework. When possible, the results of this work are compared with earlier socio-economic assessments to examine long-term trends and patterns.

Table 1.—Demographic characteristics by coastal region.

Characteristic	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Number of fishermen	162	155	233	318	868	868
Number of captains	129	124	168	217	638	868
Number of helpers	33	31	62	101	230	868
Age (average in years)	53.0	50.8	51.3	47.3	50.1	863
Age distribution (%)						
≤30 years	7.5	7.8	13.0	16.1	12.2	863
31–40	10.6	19.5	11.7	18.0	15.2	863
41–50	22.4	20.1	22.1	24.3	22.6	863
51–60	24.2	24.0	17.8	18.9	20.5	863
61–70	29.2	22.7	26.0	14.5	21.8	863
≥71	5.6	5.2	6.9	7.3	6.5	863
Fishing experience (average in years)	29.6	30.1	29.2	26.9	28.6	852
Educational attainment (%)						
Less than high school	43.4	42.1	43.9	52.2	46.6	853
High school	39.6	44.7	43.0	36.1	40.1	853
Some college or professional training	10.1	6.6	7.0	6.6	7.3	853
College or more	6.9	6.6	6.1	5.1	5.9	853
Percentage of fishermen who reside in a different municipality than where they land their catch (%)	12.7	9.4	7.3	5.7	8.1	855

Methods

This study replicated the methodology used in earlier censuses of active commercial fishermen dating back to 1988.[2] Briefly, the methodology consisted of personnel from Puerto Rico's Department of Natural and Environmental Resources (DNER) Commercial Fisheries Statistics Program (CFSP) organizing meetings in every fishing center to discuss the need for the census and to survey the commercial fishermen in attendance. Fishermen who did not attend these meetings were identified with the assistance of the presidents of the fishing centers and other fishermen present at the meetings. Port agents attempted to reach these elusive fishermen at the dock and/or at their homes. If a commercial fisherman declined to participate in the survey (or was not found), CFSP personnel tried to obtain this fisherman's information from other fishermen who knew the non-respondent (or missing fisherman). About 5% of the population of purported active commercial fishermen either declined to participate in the census or could not be reached by CFSP staff.

The questionnaire inquired about household demographics; fishing practices; catch disposition; marketing channels; capital investment in fishing vessels, gears and equipment; perceptions about the health of the fishery; and the main socio-economic issues impacting their livelihoods (Fig. 1). The fieldwork took place between January and October, 2008. The confidentiality of the data is protected by article 9 of Puerto Rico's Fisheries Law No. 278 (DRNA, 2004) and Section 402(b) of the Magnuson-Stevens Fishery Conservation and Management Act (NMFS, 2007).

Results and Discussion

In all, CFSP personnel conducted 868 in-person, voluntary interviews with commercially active fishermen around 92 fishing centers in 39 coastal communities (Fig. 2).[3] To offer detail and contextualize the findings of this work, we present regional and Commonwealth level statistics. The Commonwealth was partitioned into four coastal regions: north, east, south, and west (Fig. 2). The northern region extends from the municipalities of Isabella to Luquillo. The eastern region runs from the municipalities of Fajardo to Maunabo, including the islands of Vieques and Culebra, and the southern region stretches from the municipalities of Patillas to Lajas. The western region spans the municipalities of Cabo Rojo to Aguadilla. This section presents summary statistics for selected demographic characteristics; fishing dependence; fishing and marketing practices; capital investment on vessels, gear, and equipment; and opinions about the biological and socio-economic health of the fishery.

Demographic Profile

Most respondents were middle-aged men who lived in the same coastal municipalities where they landed their catches. Fishermen's ages ranged from 16 to 89 years, with an average of 50 years (Table 1). The northern region had older fishermen relative to the western region (53 vs. 47 years). About 12% of the respondents were 30 years or younger (Table 1), which is marginally lower than the 16% observed in the 1996 census of commercial fishermen.[4] Recruitment rates for fishermen less than 31 years of age were almost two times higher in the south and west regions than

[2] Two additional censuses of active commercial fishermen were conducted in the early 1990's. The first census estimated that there were 1,332 active fishermen in 1990 and the second one estimated that there were 1,155 active fishermen in 1992. The senior author, who participated in both of these data collections, does not believe that the above totals captured the entire population of active fishermen given the limited resources available for the sampling effort. Thus, we omitted them from our discussion.

[3] The northern coastal municipalities of Manatí, Toa Baja, and Quebradillas reported no commercial fishing activity. According to key informants, fishermen dislike operating from Manatí and Toa Baja because of the strong ocean surges and from Quebradilla because of its high cliffs. Fishermen, who reside in Quebradilla, reportedly land their catch in the coastal municipalities of Isabella and Arecibo instead.

[4] In a different study, Gutierrez-Sanchez (1982) estimated that 14.8% of the commercial fishermen were less than 30 years old (n=291).

Estado Libre Asociado de Puerto Rico

Departamento de Recursos Naturales y Ambientales

CENSO PESQUERO 2007-2008

Número de entrevista _____ Fecha _____

Entrevistador: _____

1. Nombre del pescador: _____
2. Apodo: _____
3. Lugar de desembarco (Centro): _____
4. Pertenece a alguna organización de pesca: Si __ No __ Cual _____
5. Dirección postal (Opcional): _____
6. Teléfono: (_____) - _____ - _____
7. Barrio y Municipio de residencia: _____
8. Edad: _____
9. Años de experiencia como pescador: _____
10. Número de familiares que dependen económicamente de Usted _____ (inclúyase)
11. Nivel de educación mas alto alcanzado:
    - ☐ Escuela elemental (K-Sexto) ☐ Escuela intermedia (Séptimo-Noveno)
    - ☐ Escuela superior (Décimo-Doce) ☐ Cursos técnicos (post-secundarios)
    - ☐ Algo de Universidad ☐ Grado de Universidad
    - ☐ Algo de Escuela Graduada ☐ Estudios Graduados/Profesional
12. Posee licencia: Si _____ No _____ Número (opcional) _____

    Si, tiene licencia ☐ Tiempo Completo ☐ Parcial ☐ Principiante
13. Tipo de pescador: ☐ Capitán ☐ Proel
    - ☐ Tiempo completo
    - ☐ Tiempo parcial (ocupación principal): _____
14. Cuantas horas por semana dedicas a:
    - a) Pescar _____ horas/semana
    - b) Mantenimiento y reparación de su barco y motores _____ horas/semana
    - c) Mantenimiento y reparación de artes _____ horas/semana
    - d) Venta de pescado _____ horas/semana
15. Tipo de pesca:
    - ☐ Peces de arrecife ☐ Pargos de agua profunda ☐ Carrucho ☐ Octopus
    - ☐ Peces ornamentales ☐ Pesca pelágica ☐ Juey
    - ☐ Ceti ☐ Langosta ☐ Carnada

Figure 1.—Commercial fisherman census form.

16. Localización área de pesca (caladeros):

☐ Orilla ☐ Talud o beril ☐ Plataforma insular ☐ Aguas oceánicas (Pelágico)

17. Porcentaje de la pesca expedido por los siguientes canales (que sume al 100%):

Asociación _____ % Pescadería o Comprador _____ % Ambulante _____ %

Restaurante _____ % Pescadería propia_____ %

18. Manejo de la pesca:

☐ Desbucha ☐ Desbucha c/hielo ☐ Vivero ☐Entero en hielo ☐ Entero s/hielo

19. Información sobre la embarcación:

Variables	Barco # 1 (Principal)	Barco # 2	Barco # 3
Dueño único (SI/NO)			
Año de construcción			
Eslora (pies)			
Manga (pies)			
Construcción del casco	" Madera " Fiberglass " Madera y fiber " Aluminio " Acero " Otro : _____	" Madera " Fiberglass " Madera y fiber " Aluminio " Acero " Otro : _____	" Madera " Fiberglass " Madera y fiber " Aluminio " Acero " Otro : _____
Motor	" Fuera de borda ____ " Interior ____ " Fuera de Borda / Interior ____	" Fuera de borda ____ " Interior ____ " Fuera de Borda / Interior ____	" Fuera de borda ____ " Interior ____ " Fuera de Borda / Interior ____
Propulsión (HP)	Motor # 1 ____ HP Motor # 2 ____ HP Motor # 3 ____ HP	Motor # 1 ____ HP Motor # 2 ____ HP Motor # 3 ____ HP	Motor # 1 ____ HP Motor # 2 ____ HP Motor # 3 ____ HP
Equipo eléctrico (número)	" GPS ____ " Depth finder ____ " Fish finder ____ " Radio-teléfono ____ " EPIRB ____ " Celular ____	" GPS ____ " Depth finder ____ " Fish finder ____ " Radio-teléfono ____ " EPIRB ____ " Celular ____	" GPS ____ " Depth finder ____ " Fish finder ____ " Radio-teléfono ____ " EPIRB ____ " Celular ____
Equipo de pesca (número)	" Fisga ____ " Tanques ____ " Bichero ____ " Canasto ____ " Slurp gun ____	" Fisga ____ " Tanques ____ " Bichero ____ " Canasto ____ " Slurp gun ____	" Fisga ____ " Tanques ____ " Bichero ____ " Canasto ____ " Slurp gun ____
Equipo de pesca (número)	" Winch ____ " Malacate Elect ____ " Malacate Hidr ____	" Winch ____ " Malacate Elect ____ " Malacate Hidr ____	" Winch ____ " Malacate Elect ____ " Malacate Hidr ____

Figure 1 (continued).—Commercial fisherman census form.

20. Información sobre artes de pesca:

Artes	Cantidades
Cordeles	
Cordel de mano	
Silga	
Caña (Spinning, trolling)	
Palangre horizontal	
Palangre de tiburón	
Palangres Verticales	
Fuete o Potala	
Fuete de Galonear	
Redes	
Trasmallo o filete	
Mallorquín (Peces, langostas)	
Atarraya (Carnada, camarones)	
Redes para peces ornamentales	
Submarina	
Skin	
SCUBA	
Trampas	
Nasa	
Cajones	

21. ¿Cuantos tripulantes participan en la pesca? _____

22. Opinión del Estado de los Recursos Pesqueros:

☐ Mejor ☐ Igual ☐ Peor que otros año

Razones:

☐ Contaminación

☐ Sobrepesca

☐ Destrucción de hábitat

☐ Otras _____

23. Porcentaje del ingreso del hogar (no personal) proviene de la pesca: _____ %

24. ¿Cuáles son los tres mayores problemas socio-económicos que afectan su pesca?

1. _____

2. _____

3. _____

*(Si dice reglamento especifique que regulación en particular, NR: no responde; NS: no sabe)

Figure 1 (continued).—Commercial fisherman census form.

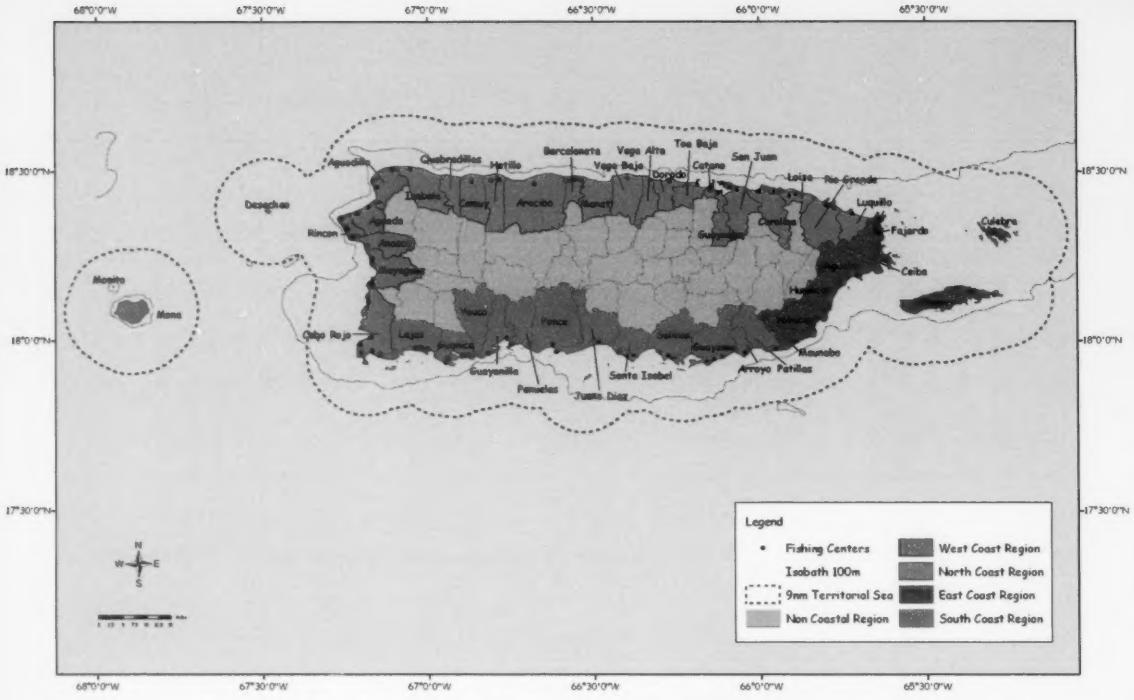

Figure 2.—Distribution of fishing centers in the Commonwealth of Puerto Rico.

in the north and east regions. Recruitment in the west coast was mainly comprised of full-time fishermen whereas recruitment in the south coast largely consisted of part-time fishermen. The presence of greater numbers of full-time fishermen in the west coast is due to the higher productivity of the local fishing grounds, the long fishing tradition of the region, and the limited employment opportunities outside the fishing industry. Part-time fishermen who live along the south coast also work for nearby petrochemical and pharmaceutical firms and produce farms harvesting tomatoes and mangos. The plurality of the respondents resided on the west (37%) coast and the remainder lived in the south (27%), north (19%), and east (18%) coasts. Only 8% of those surveyed lived in a different municipality from where they landed their catches. Seventy-four percent of the interviewees were captains and the remaining 26% were crew.

Most Puerto Rican fishermen had considerable fishing experience and moderate levels of formal education. Fishing experience ranged from 1 to 75 years, with an average of 29 years. Regionally, fishing experience was fairly uniform ranging from 27 years in the west coast to 30 years in the east coast (Table 1). Approximately 47% of the respondents did not complete high school. Forty percent of the surveyed fishermen reported that their highest educational attainment was high school and another 6% reported having a college degree (Table 1). In contrast, U.S. census data for 2000 shows that about 40% of the Puerto Rican adults (25 years or older) did not complete high school. Another 22% reported that their highest educational accomplishment was a high school diploma, and another 18% reported having a college degree (Ladd and Rivera-Batiz, 2006). These statistics illustrate that, on average, commercial fishermen have lower educational attainment levels than those of typical Puerto Rican adults, which limit their employability outside the fisheries sector. In comparing the educational attainment of Puerto Rican fishermen relative to other U.S. Caribbean fishermen, we find that Puerto Rican fishermen, on average, have more years of formal education. For example, Kojis (2004) reports that about 59% of fishermen in the U.S. Virgin Island did not complete high school, another 30% had only attained a high-school diploma, and another 5% had obtained a college degree.

Most respondents had small household sizes. The number of dependents (including the fisherman) ranged between 1 and 10, with an average of 3.1 (Table 2). Comparable figures were reported by Griffith et al. (2007) who found that the average household had 3.2 members (including the fisherman). Although there are no comparable statistics for the entire population of commercial fishermen in the U.S. Virgin Islands, Agar et al. (2008) found that the average number of dependents for trap fishermen ranged from 2.8 in St. Thomas and St. John to 3.4 in St. Croix.

Fishing Dependence

The majority of respondents were full-time fishermen (Table 2). Almost 75% of the respondents self-reported that they operated on a full-time basis, which is 39% higher than the levels reported in the 2002 census of commercial fishermen (Matos-Caraballo et al., 2005). The pointed percentage increase likely reflects the decline in construction jobs as the Puerto Rican construction boom abated. Table 3 shows that number of construction employment opportunities decreased by 15.6% between 2007 and 2008 (Junta de Planificación de Puerto Rico[5]). The elevated proportion of full-time fishermen may also be an unintended consequence of Regulation No. 6768, which requires the submission of tax records to obtain a commercial fishing license.[6] Presently, Puerto Rico's Department of Agriculture grants full-time fishermen a 90% tax exemption on their fishing income. Part-time fishermen do not receive a tax exemption; thus, they are taxed at a higher marginal rate than their full-time counterparts. Moreover, the high fuel prices experienced in 2008 may have disproportionally impacted marginal, part-time operations (Table 3). When part-time fishermen were asked about their other occupations, 81% declined to share this information, 5% said that they worked on construction and 3% stated that they received retirement benefits (i.e. pensions and social security payments). About 60% of the fishermen belonged to a fishing association (Table 2).

Most respondents stated that they were highly dependent on fishing to support their families. On average, Puerto Rican fishermen reported that fishing income made up about 75%

Table 2.—Fishing dependence indicators by coastal region.

Indicator	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Self-reported full-time fishermen (%)	64.8	78.1	76.0	77.7	74.9	868
Household income derived from fishing (%)	54.9	78.3	76.9	82.6	75.2	826
Household income derived from fishing (%)						
0–24.9	15.6	4.5	4.4	2.9	5.9	826
25–49.9	23.4	15.7	4.8	5.1	10.2	826
50–74.9	31.2	12.7	28.6	19.9	23.2	826
75–100	29.9	67.2	62.1	72	60.6	826
Number of dependents (average, including self)	3.0	3.5	2.9	3.1	3.1	837
Percentage of fishermen belonging to a fishing association (%)	85.2	53.5	66.1	48.1	60.8	868
Number of licensed fishermen	92	114	134	217	557	868
Full-time licenses	53	80	96	165	394	868
Part-time licenses	10	14	13	9	46	868
Beginner licenses	29	20	25	43	117	868

[5] Junta de Planificación de Puerto Rico. 2010. Estadísticas Económicas. Online at http://www.jp.gobierno.pr/.

[6] Full-time fishermen are required to show their state income tax returns to document that 50% or more of their income is derived from fishing whereas part-time fishermen need to show that fishing contributes between 20 and 49% of their income. The regulation also provides for a third type of license, the so-called 'beginner' ('principiante' in Spanish) or apprentice license, which does not have any income reporting requirements but only lasts for a year and cannot be renewed. Full-time and part-time licenses can be renewed every four years.

Table 3.—Number of fishermen and construction jobs, commercial landings, and retail gasoline price over time.

Year	No. of active fishermen (census data)	No. of full-time active fishermen (census data)	No. of part-time active fishermen (census data)	Adjusted landings[1] (lb)	Construction jobs (1,000's)[2]	% Change in construction jobs	Retail gasoline price (nominal $/gal., U.S. city)[3]
1988	1,731	1,306	425	3,837,386	–	–	0.96
1989				4,808,093	55	–	1.06
1990				4,560,774	56	1.8	1.22
1991				5,137,710	54	–3.6	1.20
1992				3,624,480	57	5.6	1.19
1993				4,449,363	56	–1.8	1.17
1994				4,511,971	55	–1.8	1.17
1995				5,557,385	58	5.5	1.21
1996	1,758	1,262	496	5,419,597	61	5.2	1.29
1997				5,313,666	66	8.2	1.29
1998				4,776,180	74	12.1	1.12
1999				4,551,945	83	12.2	1.22
2000				6,276,077	82	–1.2	1.56
2001				5,301,956	84	2.4	1.53
2002	1,163	423	740	4,048,506	83	–1.2	1.44
2003				3,364,452	85	2.4	1.64
2004				2,626,310	89	4.7	1.92
2005				2,209,908	85	–4.5	2.34
2006				1,761,742	91	7.1	2.64
2007				1,971,432	90	–1.1	2.85
2008	868	650	218	2,006,786	76	–15.6	3.32
2009				–	59	–22.4	2.40

[1] Cummings, N., and S. Turner. 2009. Southeast Fisheries Science Center, NMFS, NOAA. Personal commun.

[2] See text footnote 5.

[3] Department of Energy. 2010. Online at http://www.eia.doe.gov/emeu/aer/txt/ptb0524.html.

of their household income (Table 2).[7] Eighty-four percent of the interviewees stated that income derived from fishing contributed in excess of 50% to their household income. Parsing fishing income by time devoted to fishing, we find that self-reported full-time fishermen obtained 84% of their household income from fishing whereas self-reported part-time fishermen drew 47% of their household income from fishing. The documented levels of fishing reliance were higher than fishing dependence statistics reported elsewhere, suggesting that the loss of employment opportunities in construction, escalating fuel costs, and regulatory tightening (e.g. licensing requirements, seasonal closures, and minimum size restrictions) may have discouraged fishing on a part-time basis. For example, Griffith et al. (2007) estimated that fishing activities contributed between 40% and 45% to the average fisherman's household income.

Fishing dependence levels were more pronounced in the west (83%), followed by the east (78%), south (77%), and north (55%). The western region exhibited the highest levels of dependence on fishing because it encompasses the most productive fishing area and has the highest number of full-time fishermen. Conversely, the northern region had the lowest levels of dependence because it has the least productive fishing grounds and has the lowest number of full-time fishermen. The northern region also has an important pharmaceutical and retail industry.

Of the 868 fishermen interviewed, 557 self-reported to have valid licenses, with 394 full-time licenses, 46 part-time licenses, and 117 apprentice (or beginner) licenses (Table 2). By contrast, the DNER license database (which became available after our data collection was completed) indicated that there were 1,129 valid licenses in February 2009 (416 apprentice, 89 part-time, and 624 full-time licenses).[8] Although there is a significant discrepancy between the DNER figures and ours, we believe that our tally provides a better estimate of the population of active (rather than licensed) fishermen since they were derived from extensive fieldwork. Our surveyors, mainly port agents, combed all fishing centers searching for active fishermen. Moreover, DNER's statistics likely capture a large share of opportunistic fishermen on the main island of Puerto Rico who occasionally harvest spiny lobster using trammel nets and king mackerel using handlines, which would explain the large number of beginner licenses. Similarly, on the island of Vieques, a large number of opportunistic fishermen reportedly fish for mutton and yellowtail snappers every year between February and April. Regardless of the reasons behind the discrepancy, this study, which adopted the same methods used in earlier censuses of active fishermen, shows that participation rates have decreased noticeably since the late 1980's (Matos-Caraballo and Torres-Rosado, 1989; Matos-Caraballo, 1998; Matos-Caraballo et al., 2005).

Of the captains interviewed, about 75% indicated having a valid license (350 full-timers, 42 part-timers, and 85 apprentices). Noteworthy is that 35% of helpers had a valid license (44 full-timers, 4 part-timers and 32 apprentices) because captains encourage helpers to acquire them to maximize the daily harvest of queen conch. Commonwealth regulations allow landings of 150 queen conch per day per licensed fisherman up to 450 queen conch per day per fishing vessel. Helpers also like having a fishing license because it affords greater flexibility to go fishing alone or with other helpers.

Table 4.—Main fishing grounds and target species by coastal region.

Item	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Average hours per week spent on fishing related activities						
Fishing	28.5	31.0	30.7	31.1	30.5	849
Maintaining and repairing vessel and engine	3.9	3.6	5.1	6.6	5.1	785
Maintaining and repairing fishing gear	3.9	3.2	6.2	6.1	5.1	777
Selling catch	3.5	3.0	4.6	3.9	4.4	829
Percentage of fishermen who fish in following areas (%)						
Shore	66.7	47.7	21.9	13.5	31.8	868
Shelf break	84.0	67.1	44.6	51.3	58.4	868
Continental shelf	90.1	83.9	92.7	70.4	82.5	868
Deep water	45.7	60.7	24.5	25.8	35.4	868
Percentage of fishermen who target the following species (%)						
Reef fish	88.3	75.5	88.0	64.8	77.3	868
Deepwater snapper	71.6	71.6	39.5	51.3	55.5	868
Pelagic species	65.4	66.5	30.0	26.4	41.8	868
Spiny lobster	27. 8	64.5	57.1	47.2	49.3	868
Queen conch	13.0	34.8	45.1	34.6	33.4	868
Baitfish	53.1	32.9	30.9	17.9	30.7	868
Octopus	1.9	0	19.3	1.3	6.0	868
Sirajo goby	8.0	0	0.9	0	1.7	868
Land crab	9.3	10.3	6.0	2.2	6.0	868
Ornamental fish	0.6	1.9	0.9	2.5	1.6	868

Fishing Practices

Puerto Rican fishermen devoted, on average, 30 h per week to catching fish (Table 4). They also spent a substantial amount of time maintaining their vessels, engines, and gears. On average, fishermen reported spending about 5.1 h a week maintaining and repairing their vessel and engine and an additional 5.1 h a week maintaining and repairing their fishing gear (Table 4). These statistics suggest that Puerto Rican fishermen spent more time on trade-related activities than their counterparts in the U.S.

[7] Similar levels of fishing dependence have been reported for the commercial fishing fleet in the U.S. Virgin Islands. According to Kojis (2004), fishermen from St. Thomas and St. John derived about 74% of their household income from fishing and fishermen from St. Croix derived about 60%.

[8] Miguel Garcia Bermudez of DNER reported these statistics to Caribbean Fishery Management Council in June 2009. Personal commun.

Virgin Islands. Kojis (2004) reported that fishermen in the U.S. Virgin Islands spent an average of 22.3 h per week fishing, 3.2 h per week fixing their vessel, and 4.1 h per week fixing their gear.

When we inquired about the time spent on these trade-related activities by time devoted to fishing, we found that self-reported full-timers, on average, spent 33.3 h per week fishing, 5.5 h per week maintaining their fishing boats, and 5.5 h per week maintaining their fishing equipment and gears. On the other hand, self-reported part-timers reported that, on average, they spent 21.5 h per week fishing, 4.1 h per week maintaining their fishing boats, and 3.1 h per week maintaining their fishing equipment and gear.

Table 5.—Type and number of fishing gears by coastal region.

Gear	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Handline	1,040	1,260	1,746	1,715	5,761	868
Troll line	368	464	300	313	1,445	868
Rod and reel: spinning	54	96	74	67	291	868
Rod and reel: trolling	344	101	287	187	919	868
Horizontal longline	36	21	38	60	155	868
Shark longline	13	45	8	12	78	868
Anchored bottom line	480	276	224	193	1,173	868
Drifting bottom line	158	3	27	234	422	868
SCUBA	15	58	54	90	217	868
Skin	27	60	37	18	142	868
Fish traps	241	1,587	1,661	1,075	4,574	868
Lobster traps	99	880	1,761	1,102	3,842	868
Deepwater snapper traps	79	419	86	597	1,181	868
Gillnet	104	104	216	146	570	868
Fish trammel net	10	26	46	93	175	868
Lobster trammel net	0	0	49	103	152	868
Bait cast net	202	210	229	169	810	868
Shrimp cast net	2	0	3	0	5	868
Ornamental net	0	0	4	12	16	868

Fishing Grounds and Target Species

Puerto Rican fishermen continue to favor the continental shelf and shelf break as their prime fishing grounds (Table 4). About 82% of respondents reported fishing on the continental shelf which is about the same as the 83% who reported fishing on the continental shelf in 2002 (Matos-Caraballo et al., 2005).[9] In 1996, 70% of the fishermen stated that they fished on the continental shelf (Matos-Caraballo, 1998). Fifty-eight percent of the fishermen stated that they fished on the shelf break, which is up from 19% in 2002 and 43% in 1996 (Matos-Caraballo, 1998; Matos-Caraballo et al., 2005). In contrast, the proportion of fishermen who reported fishing in deep waters dropped from 46% in 1996 and 48% in 2002 to 35% in 2008, because of higher fuel costs and tighter fishing regulations such as minimum size limits and closed seasons. Higher fuel costs also may have contributed to a greater percentage of fishermen operating from the coast, which rose from 17% in 2002 to 32% in 2008 (Matos-Caraballo et al., 2005). In 1996, 31% of the fishermen reported fishing from the coast (Matos-Caraballo, 1998).

We also inquired about fishermen's targeting behavior (Table 4). A high proportion of respondents stated that they targeted reef fish (77%), spiny lobster (49%), queen conch (33%), and baitfish (31%). Unexpectedly, census figures showed that the percentage of fishermen targeting deepwater snappers increased from 37% in 2002 to 55% in 2008 despite fewer fishermen reporting having operated in deep waters. It is likely that they are taking advantage of the higher prices received for deepwater snappers, which command an average price of $3.50/lb whereas first class reef fish species (e.g. yellowtail and lane snappers) fetch about $2.25/lb. The proportion of fishermen seeking pelagic species also increased from 36% to 42% during the same time period. Few respondents stated that they targeted octopi (6%), land crabs (6%), sirajo gobies (2%), and ornamentals (2%).[10]

Next, we consider how the choice of gears and targeting behavior varies by region. In discussing these choices, the island's unique biogeography must be taken into consideration.

North Coast

The north region is the least productive region of the island largely because of its narrow continental shelf and exposed coast (Jarvis, 1932; Whiteleader, 1971; Suarez-Caabro, 1979). The 100-fathom curve occurs between 1 and 2 miles off the coast, which limits the amount of fishable area. In 2008, this coast produced about 7% of the total reported landings for Puerto Rico.[11] The limited shelf forces the fishermen to operate in a variety of locations, including the continental shelf (90%), shelf break (84%), shore (67%), and, to a lesser extent, in deep waters (46%; Table 4). The exposed coast offers little protection against heavy swells and rough seas from the Atlantic Ocean, which encourages the use of hook and line and, to a lesser extent, net gears, and discourages the use of traps and SCUBA. This region holds about 41% of the anchored bottom lines present on the island, 37% of the drifting bottom lines, 37% of rods and reels for trolling, and 23% of the horizontal longlines (Table 5). Less than 5% of the total number of

[9] One of the reviewers correctly pointed out that since the descriptions of fishing grounds and targeting behavior contain the views of captain and crew there may be some 'double counting' of the results. While we recognize this limitation, we did not make any changes since we are comparing these results with the results of earlier censuses, which also suffer from the same shortcoming identified by the reviewer.

[10] Sirajo gobies are an anadromous species whose adults spawn in freshwater, but their young spend time at sea or in brackish waters. A unique trait of these species is that when the adults return upstream to spawn they climb rocks (or any barriers impending their upstream movements) with their modified pelvic fins. Fishermen also refer to gobies as cetí or 'chupapiedras' (suckstones). Benedetti (1996) offers an interesting account of this fishery, and describes how fishermen catch this species on river mouths between June and January on a waning moon.

[11] Transmission from Daniel Matos-Caraballo, Fisheries Research Laboratory, Department of Natural and Environmental Resources, Mayagüez, Puerto Rico, to Josh Bennett, Southeast Fisheries Science Center, National Marine Fisheries Service, Miami, Florida on 5/1/2009.

fish, spiny lobster, and deepwater snapper traps are found in this area. Fewer than 7% of the SCUBA divers operate in the area.

Fishermen along the north coast target a variety of species (Table 4). About 88% of the fishermen target reef fishes such as yellowtail snapper; triggerfish, *Balistidae* spp.; and parrotfish, *Sparisima viride* and *S. chrysoterum*; 72% target deepwater snappers such as silk and queen, *Etelis oculatus*, snappers; 65% target pelagic species such as dolphinfish, *Coryphaena hippurus*; king mackerel, *Scomberomorus cavalla*; and little tunny, *Euthynnus alletteratus*; and 53% target baitfish such as herring, *Opisthonema oglinum*; mullets, *Mugilidae spp.*; and mojarras, *Gerreidae* spp. About 28% of the fishermen reported catching spiny lobster and another 13% landing queen conch. A small number of fishermen reported catching land crabs (9%) and sirajo gobies (8%) in the lower reaches of streams and lagoons and along mangrove edges.

East Coast

The east coast has an extensive shallow shelf with average depths of about 30 fathoms, and a number of reefs, banks, islets, and cays (Jarvis, 1932). In 2008, this area was responsible for about 11% of the domestic seafood production.[11] About 84% of the fishermen stated that they fished on the continental shelf, followed by the shelf break (67%), deepwater (61%), and shore (48%; Table 4). The shallow, ample shelf permits them to target multiple species with various gears, including lines, traps, and SCUBA (Table 5). About 75% of the fishermen stated that they target reef fish species such as yellowtail; lane and mutton snappers; hogfish, *Lachnolaimus maximus*; porgies, *Sparidae* spp.; white grunt, *Haemulon plumieri*; and parrotfish; 72% target deepwater silk and queen snappers, 66% target pelagic species such as mackerels, 64% target spiny lobster, 35% target queen conch, and 33% target baitfish (Table 4). Ten percent of the fishermen mentioned that they harvested land crabs.

The region accounted for 58% of the shark longlines, 32% of troll lines, 33% of the rod and reel (spinning), 23% of the anchored bottom lines, and 30% of the traps (both lobster and fish) present on the island (Table 5). This region also includes 42% of the skin divers and 27% of the SCUBA divers of the island.

South Coast

Although the southern platform drops off within a short distance from the coast, the coastline is not as exposed or subject to strong storms as the northern coast (Jarvis,1932). This region yielded about 24% of the domestic catch in 2008.[11] SCUBA, fish traps or pots, bottom lines, and, to lesser extent, nets are responsible for most of the landings. Ninety-three percent of the fishermen stated fishing on the continental shelf compared to 45% on the shelf break, 24% in deep water, and 22% from the shoreline (Table 4). Because the shelf does not drop off abruptly and the coastline is less exposed to rough seas relative to the north coast, more fishermen target spiny lobster (57%) and queen conch (45%) (Table 4). Eighty-eight percent of fishermen mentioned that they harvested reef fish species such as yellowtail, mutton and lane snappers, porgy, parrotfish, hogfish, and grunts; 39% said they targeted deepwater snappers such as silk snapper; 30% reported that they caught pelagic species such as dolphinfish and king mackerel; and 31% said that they targeted baitfish such as ballyhoo, *Hemiramphus brasiliensis*; and herring. The south coast had the highest percentage of respondents that said that they fished for octopus (19%).

West Coast

Although the western coastline is about a third as long as the northern or southern coasts, it is Puerto Rico's most productive fishing region. In 2008, the west coast landed about 59% of the finfish and shellfish catch.[11] The southwest corner has a relatively shallow and extended shelf (10–15 fathom depths are found for 6 or more miles off Mayagüez) whereas in the northwest corner the ocean floor drops off sharply (Jarvis, 1932; Whiteleader, 1971; Suarez-Caabro, 1979). Off the west coast, fishermen also fish around the islands of Mona, Monito, and Desecho and deepwater banks (e.g. Bajo de Sico, Tourmaline, Abrir la Sierra, among others). Bottom lines, SCUBA, and, to a lesser extent, troll lines and fish pots are the most important gears used in this region. As in other coastal areas, fishermen fished in various areas: continental shelf (70%), shelf break (51%), deep water (26%), and the shoreline (13%) (Table 4). Sixty-five percent of the fishermen reported fishing for reef fish such as yellowtail, lane, and mutton snappers; 51% fished for deepwater snappers such as silk and queen snappers; 26% fished for pelagic species such as dolphinfish; skipjack, *E. pelamis*; blackfin, *Thunnus atlanticus*; and yellowfin, *T. albacarus*, tunas; and king mackerel; and 18% fished for baitfish such as ballyhoo (Table 4). Forty-seven percent and 35% of the fishermen reported targeting spiny lobster and queen conch, respectively. Twelve out of the 16 ornamental fishermen interviewed were found in this coastal region.

Catch Disposition and Marketing

In 2008, about 2 million pounds of finfish and shellfish were landed in Puerto Rico (Table 3). On average, Puerto Rican fishermen spent about 4.4 h per week selling their catch (Table 4). Over 55% of the respondents stated that they iced their catch. Over 33% said they sold their catch iced in whole form, and another 22% mentioned that they sold their catch iced in gutted form (Table 6).

The census showed that respondents use multiple avenues to sell their catches (Table 6). About 36% of the respondents stated that they peddled their catch themselves (locally known as "ambulantes"), up nearly 8% from 2002 levels (Matos-Caraballo et al., 2005). Peddlers use multiple marketing strategies, including delivering fish orders to the homes of their regular clients, packing their catch in iced fiberglass boxes and hauling them to strategic locations where they are put up for sale, and selling directly from

their homes (Valdés-Pizzini[12]). Fishermen favor peddling fish because of the minimum storage and freezing investments necessary to market their low volume production and the opportunity to generate additional income which otherwise would go to fish mongers and wholesalers (Valdés-Pizzini[12]).

The proportion of fishermen selling to fishing associations dropped from 47% in 2002 to 28% in 2008 because of the economic downturn (Table 6).[13] Unlike most countries where fresh fish is preserved in ice, most Puerto Rican fishing associations sell the fish frozen, even though they market it as "fresh" fish ("pescado fresco"). "Pescado fresco" seems to denote, at least in Puerto Rico, that the fish is caught locally rather than not frozen. Fish mongers keep locally caught fish in freezers in either gutted ("limpio" as referred locally) or un-gutted ("sucio" as referred locally) form.

Margins vary by fish species and customer type. For instance, fishermen may receive $5.00/lb for queen conch meat and then the fishing association may subsequently sell it for $5.75/lb to restaurants or $6.50/lb to retail customers. Lobstermen may obtain $6.25/lb for spiny lobster and then the fishing association may sell it for $7.00/lb to restaurants or $7.25/lb to the public. Similarly, reef fish fishermen may receive $3.00/lb for gutted silk snapper and then the fishing association may sell it for $5.25/lb to restaurants or $5.50/lb to the public. Fishing associations raise dockside prices slightly ($0.25–$1/lb) during Lent to satisfy increasing demand during this period.

Few fishermen reported selling directly to fish stores and restaurants. The share of fishermen selling through their retail store increased marginally from 3% in 2002 to 6% in 2008 while the percentage of fishermen selling to restaurants remained relatively constant at about 6% during the same time period (Table 6). During the interviews many fishermen complained that it was hard to sell to restaurants because they favor low-cost, frozen fish products from the U.S. mainland, Brazil, and Mexico. The share of fishermen selling to fish houses or wholesalers went marginally up from 30% in 2002 to 33% in 2008 (Matos-Caraballo et al., 2005).

The census also inquired about the share of landings that went through various marketing channels. On average, 32% of the catch was peddled, 30% was sold to wholesalers or fish houses, and 26% was sold to fishing associations (Table 6). Regionally, peddling was the dominant marketing strategy in the north (38%) and south (38%) coasts. The east and west coasts peddled about 30% and 25% of their production, respectively. In the west coast, most of the landings were handled by wholesalers or fish houses (40%) and fishing associations (21%).

Table 6.—Marketing of finfish and shellfish by coastal region.

Item	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Percentage of fishermen who sold through these marketing channels (%)						
Fishing association (Villa pesquera)	40.7	25.8	29.6	21.1	27.9	868
Wholesaler/fish store	20.4	38.1	26.6	41.2	32.8	868
Own fish store	7.4	7.1	6.4	3.8	5.8	868
Home-based retail (ambulantes)	45.7	38.1	40.3	26.7	35.9	868
Restaurant	2.5	7.1	1.7	10.1	5.9	868
Percentage of catch sold through these marketing channels (%)						
Fishing association (Villa pesquera)	34.1	23.7	28.9	20.5	25.9	868
Wholesaler/fish store	17.9	30.5	25.3	40.4	30.4	868
Own fish store	6.2	6.8	6.4	3.7	5.5	868
Home-based retail (ambulates)	37.9	29.5	37.6	25.2	31.7	868
Restaurant	1.5	4.4	1.0	9.2	4.7	868
Percentage of the catch disposed in the following manner (%)						
Whole	13.0	12.9	17.6	19.8	16.7	868
Whole and iced	72.2	52.9	18.9	15.1	33.5	868
Gutted	0	3.2	28.3	40.9	23.2	868
Gutted and iced	10.5	7.7	36.9	23.9	22.0	868
Live well	1.8	21.3	0.4	5.4	6.2	868

Fishing Vessels, Gears, and Equipment

Fishing Vessels

The active commercial fleet consisted of 670 vessels (Table 7). Almost 100% of the captains owned a single (primary) fishing boat. Most of the fishing vessels were small with moderate levels of mechanization. The average length of the primary fishing vessel was 20 ft. About 97% of the primary vessels ranged between 10 and 30 ft in length.

The census tallied 637 gasoline engines and 65 diesel engines (Table 7). Most primary vessels were outfitted with single outboard engines. The average propulsion rate of the primary vessel was 80 horsepower (hp), up from 66 hp in 2002 (Matos-Caraballo et al., 2005). Regionally, propulsion rates ranged from 65 hp (48 hp in 2002) in the south region to 103 hp (79 hp in 2002) in the east region (Table 7). Most hulls were built of fiberglass (65%) and, to a lesser extent, of fiberglass and wood (22%; Table 7). Only 12% of the hulls of the primary vessels were made of wood. Thirty percent of the primary vessels were built after 2000. Most fishing vessels were manned by a captain and helper (Table 7). Diving operations tended to have a captain and two helpers because the crew need to tend the boat and dive.

Main Gears

Hook and line gear was the most common and productive gear, accounting for about 49% of the total landings in 2008.[11] Fishermen, particularly part-time fishermen, favored this gear because of its efficiency and cost effectiveness for catching reef fish and pelagic species. Table 5 shows that handlines comprised about 56% of the

[12] Valdés-Pizzini, undated. Canales de Mercadeo de Pescado Fresco en Puerto Rico. Unpublished manuscript.

[13] According to Eugenio Piñeiro-Soler, Chairman of the Caribbean Fishery Management Council, many fishing associations have not only scaled down on the volume of their purchases but also limited the time of operation from 7 to 4 days per week (i.e. Thursdays to Sundays). Personal commun.

units in this group, followed by bottom lines (16%), troll lines (14%), rods and reels (12%), and longlines (2%). Handlines and troll lines were used to catch dolphinfish, skipjack, little and blackfin tunas, and king mackerel. Anchored bottom lines targeted queen, silk, and lane snappers; and drifting bottom lines sought yellowtail and mutton snappers; dolphinfishes; king and cero, *S. regalis*, mackerels; little, skipjack, and blackfin tunas; and sharks. Rods and reels were used to land dolphinfish, yellowtail snapper, king and cero mackerels, and little tunny. Longlines were used to catch sharks and lane, silk, and mutton snappers. Overall, the total amount of hook-and-line gear decreased from 12,314 units in 2002 (Matos-Caraballo et al., 2005) to 10,244 units in 2008 (Table 8).

SCUBA and skin diving were the second most productive gears, together they were responsible for approximately 29% of the total landings in 2008.[11] Divers made up about 44% of the population of active fishermen, down from 53% in 2002 (Matos-Caraballo et al., 2005). SCUBA gear was used primarily to harvest queen conch and spiny lobster and, to a lesser extent, hogfish; parrotfish; boxfish, *Ostraciidae* spp.; and queen triggerfish, *B. vetula*; whereas skin diving mainly caught queen conch and spiny lobster. SCUBA and skin divers used 322 snares, 375 spears, 775 tanks, 578 gaffs, and 275 baskets (Table 8).

Traps or pots were the third most productive gears and accounted for almost 13% of the total landings in 2008.[11] Table 5 shows that fish traps accounted for 48% of the trap units, followed by lobster traps (40%) and deepwater snapper traps (12%). Fish pots targeted spiny lobsters, grunts, boxfishes, queen triggerfishes, and parrotfishes, whereas lobster traps landed mainly spiny lobsters. Deepwater snapper traps caught silk, queen, vermilion, and blackfin snappers. The total number of traps dropped from 13,146 units in 2002 (Matos-Caraballo et al., 2005) to 9,597 units in 2008 (Table 8).

Nets were the fourth most productive gears. Over 9% of the island's total yield was derived from this gear in 2008.[11] Nets totaled 1,712 units in 2008, down from 2,798 units in 2002 (Matos-Caraballo et al., 2005). Among the nets, gillnets accounted for 33% of the units, trammel nets for 19%, and bait cast nets for 47% (Table 5). Gillnets are used to catch bar jacks, porgies, ballyhoos, grunts, parrotfishes, and various snappers, whereas trammel nets catch spiny lobsters, grunts, parrotfishes, and boxfishes.

The census also examined the ornamental industry, which operated with little government intervention since the 1960's. However, this changed when regulation No. 6768 mandated that ornamental fishermen had to obtain a fishing license and an ornamental permit, and had to report their landings on a monthly basis. Moreover, the new regulation limited the ornamental fishery to 20 fish species and 8 invertebrate species (Matos-Caraballo and Mercado-Porrata, 2008). Because the ornamental fishery was only recently regulated, ornamental fishermen were not interviewed in earlier censuses of active fishermen. This survey identified 16 ornamental fisher-

Table 7.—Vessel characteristics by coastal region.

Characteristic	North coast	East coast	South coast	West coast	Puerto Rico	*n*
No. of fishing vessels	134	124	176	236	670	868
No. of gasoline and diesel engines	132	134	181	255	702	868
Average length of primary vessel (ft)	18.8	21.0	19.2	19.9	19.7	624
Average total engine propulsion of primary vessel (hp)	78.2	103.1	64.9	80.1	80.1	642
Average crew size	1.9	2.0	1.9	1.9	1.9	847
Percentage of primary vessels whose length lies between						
<10 ft	0	1.8	0.6	0	0.5	624
10–19.9 ft	55.0	16.5	55.8	52.5	47.6	624
20–29.9 ft	45.0	75.2	43.0	44.8	49.7	624
30–39.9 ft	0	6.4	0.6	2.3	2.1	624
≥40 ft	0	0	0	5	0.2	624
Percentage of primary vessels being built between						
≤1979	24	22.6	17.9	23.1	21.8	583
1980–1989	17.8	21.3	25.3	17.5	20.2	583
1990–1999	25.6	34.7	27.2	28.6	28.3	583
≥2000	32.6	21.3	29.6	30.9	29.7	583
Percentage of primary vessels that have hulls made of						
Aluminum	1.5	0	1.2	0.4	0.8	641
Fiberglass	72.0	82.9	48.8	62.3	64.7	641
Wood	9.8	0.8	15.7	18.2	12.5	641
Fiberglass and wood	16.7	16.3	34.3	18.6	21.8	641

Table 8.—Number of fishing gear and equipment by coastal region.

Gear/equipment	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Total lines	2,493	2,266	2,704	2,781	10,244	868
Total skin/SCUBA	42	118	91	108	359	868
Total traps	419	2,886	3,508	2,774	9,587	868
Total nets	318	340	543	511	1,712	868
Global Positioning System (GPS)	47	60	32	120	259	868
Depth finders	62	37	40	75	214	868
Fish finders	60	60	35	41	196	868
Radios	62	29	40	70	201	868
Emergency Position Indicating Radio Beacons (EPIRB)	0	6	5	24	35	868
Cellular phones	94	95	72	132	393	868
Electric reels	89	24	35	69	217	868
Hydraulic reels	1	8	10	17	36	868
Winches	22	41	26	37	126	868
Snares	23	101	78	120	322	868
Spears	52	85	136	102	375	868
Tanks	74	192	204	305	775	868
Gaffs	82	68	256	172	578	868
Baskets	12	70	82	111	275	868
Slurp guns	0	1	0	2	3	868

men who used slurp guns and ornamental hand nets to make a living. However, interviewees suggested that there were an additional 20 fishermen who operated illegally. Most of the respondents were skin divers who operated on rocky beaches on the northwest coast. Many of these ornamental fishermen are university or high school students who operate on a part-time basis. The ornamental fishermen interviewed reported that their operations were small in scale because they had difficulty competing with competitively priced fish from the Indo-Pacific region.

Electronic Equipment

Cellular or mobile phones and global positioning systems (GPS) were the most common electronic equipment found onboard commercial fishing vessels (Table 8). About 59% of the vessels carried cellular phones and 39% had GPS. Regionally, cellular phones were ubiquitous in the east (77%) and scarcer in the south (41%) whereas GPS were more common in the west (51%) and less prevalent in the south (18%). Slightly less than one-third of the vessels had depth finders (32%), radios (30%), and fish finders (29%). Less than 5% of the fleet had emergency position indicating radio beacons (EPIRB's). Over 32% of the vessels had electric reels, and 5% had hydraulic reels. The north region had the highest percentage (66%) of vessels with electric reels (Table 8). Approximately one in five vessels had winches. Regionally, winches were relatively more prevalent in the east (33%) and less common in the south (15%).

Perceptions About the Biological and Economic Health of the Fishery

Forty-six percent of the respondents believed that the health of the stocks was worse than in previous years whereas 45% believed that the health of the stocks was about the same (Table 9). When we inquired about the main reasons for the perceived decline, equal percentages of the fishermen (28%) stated that pollution and other (miscellaneous) reasons were to blame, 12% ascribed it to habitat destruction, and 9% believed it was due to overfishing (down from 22% in 2002). On a regional level, fishermen identified contamination as the dominant reason for the declining stocks in the north (49%), east (32%), and south (29%). According to the fishermen interviewed, large population centers and the pharmaceutical industry are the main culprits for pollution in the north coast, large marinas and extensive coastal development are the main reasons for contamination in the east coast, and the oil refinery industry and agricultural run-off are the main sources of contamination in the south. When inquired about the "other reasons" for the declining condition of fish stocks, a plurality of the fishermen stated that they were troubled by existing regulations such as closed seasons (36%), adverse weather and ocean conditions (32%), and climate change (15%). Fishermen argued that seasonal closures which prevent them from targeting dense fish aggregations lead to fewer fish being caught, which managers mistakenly ascribed to dwindling populations rather than to the pre-emptive nature of the closure.

Commercial fishermen were also asked about the main socioeconomic issues affecting their ability to support themselves and their families (Table 9). Overwhelmingly, fishermen cited high fuel costs (60%) as the most important socio-economic concern, followed by restrictive regulations (e.g. seasonal closures, minimum size limits, 35%), rising non-fuel related fishing expenses (e.g. bait, fishing equipment, 24%), adverse weather and ocean conditions (14%), and low fish prices and/or slow sales (10%).

When fishermen were asked about their main concerns about the new regulatory framework, most fishermen said that they were troubled by the new burdensome licensing and permitting requirements. Large numbers of fishermen, especially older fishermen, were opposed to reporting their fishing income to secure a fishing license because they feared having to pay income taxes, and more importantly, potentially losing public assistance and health care benefits. United States and Puerto Rican government transfer payments (i.e. Social Security and Nutritional Assistance Program) are important supplemental sources of household income, particularly to older commercial fishermen (Perez, 2005). Moreover, many fishermen claimed that Puerto Rico's DNER license application process was slow and that it sometimes

Table 9.—Perceptions about the biological and socio-economic condition of the fishery by region.

Perception	North coast	East coast	South coast	West coast	Puerto Rico	*n*
Perception about the condition of the stocks (%)						
Better off than other years	2.6	16.9	3.5	11.0	8.4	843
Same than other years	41.7	35.9	48.7	49.2	45.4	843
Worse off than other years	55.8	47.2	47.8	39.7	46.1	843
Reasons for the declining condition of fish stocks (%)						
Overfishing	10.5	5.8	9.4	9.7	9.1	868
Pollution	48.8	31.6	29.2	16.0	28.5	868
Habitat destruction	15.4	23.2	12.0	5.7	12.3	868
"Other reasons"	24.1	21.3	30.0	31.1	27.8	868
"Other reasons" for the declining condition of fish stocks (%)						
Regulations	17.9	39.4	37.1	41.1	36.1	241
Weather and ocean conditions	46.1	24.2	35.7	26.3	31.9	241
Climate change	5.1	9.1	22.9	15.1	14.9	241
User conflicts	7.7	9.1	4.3	9.1	7.5	241
Coastal development	1.0	6.1	0	2.0	3.3	241
Main socio-economic issues (%)						
High fuel costs	79.6	43.2	56.2	60.1	59.7	868
High fishing costs (excluding fuel)	15.4	20.0	26.6	27.7	23.7	868
Regulations	28.4	22.6	37.8	42.4	35.0	868
Weather and ocean conditions	15.4	10.3	20.6	9.8	13.8	868
Coastal development	13.6	1.9	6.9	4.1	6.2	868
User conflicts	1.2	2.6	2.6	2.5	2.3	868
High cost of life	15.4	13.5	4.7	3.8	7.9	868
Low fish prices and slow markets	14.2	25.2	5.11	5.0	10.4	868

took in excess of six months to receive their licenses.

Another commonly voiced complaint was that the closed seasons prevented them from targeting highly profitable spawning aggregations. Federal and Commonwealth fishery management agencies favor closed seasons over permanent closures to provide for sustained participation of small-scale fishermen while affording added protection to snapper-grouper stocks (Tonioli and Agar, 2009). In addition, fishermen objected to increasing the minimum size of many deepwater snapper-grouper species because of the forgone revenues and also because it forced them to discard dead fish, which they consider wasteful since these species do not survive the ascent to the surface once hooked. Matos-Caraballo (2009) notes that for certain snapper-grouper species, such as silk snapper, about 90% of the landings are made up of sexually immature fish. Finally, fishermen shared their frustration about what they considered to be an excessive number of safety inspections at sea. Many fishermen suggested that the number of inspections could be reduced if DNER rangers provided a form indicating that safety requirements were met, which could be made available so that safety inspections would not have to take place every couple of months.

Conclusions

The study provides a detailed characterization of the population of active small-scale commercial fishermen, describes fishermen's perceptions about the biological and socio-economic condition of the fishery and discusses their attitudes towards Regulation No. 6768. This socio-economic assessment identified 868 active fishermen scattered around the island. Most of these fishermen were middle-aged men with moderate levels of formal education and high levels of fishing dependence, which limited their ability to secure employment outside the fishery. Most of the vessels were small (20 ft) and had a single outboard engine (80 hp). Hook and line and SCUBA continued to be the dominant gears because of their versatility and cost effectiveness. Higher fuel costs appear to have prompted more fishermen to operate closer to the shore. This census also showed that the number of active commercial fishermen decreased by about 50% since 1988. The estimated number of active fishermen was 1,731 in 1988; 1,758 in 1996; 1,163 in 2002; and 868 in 2008 (Matos-Caraballo and Torres-Rosado, 1989; Matos-Caraballo, 1998; Matos-Caraballo et al., 2005). The reported lower participation rates seem to be a function of a lower resource base, escalating fuel costs, and tighter regulations. Less than half of the fishermen interviewed felt that the condition of the stocks had worsened over the past few years.

Another objective of this work was to investigate the attitudes that fishermen harbored towards the new regulations. The survey revealed that there was widespread discontent concerning the licensing and permitting requirements and many of the regulations, particularly those dealing with minimum size limits and seasonal closures. Regardless whether many of the statements offered were sincere or strategic, the survey underscored that fishermen felt estranged from the decision-making process and that a more participatory process is required to move forward. This participatory process would require fishery managers to make a concerted effort to educate and disseminate information about the condition of the stocks and performance of regulations, as well as afford fishermen greater input in the decision-making process so that fishermen feel that they are sharing the benefits and costs of conservation (Pomeroy et al., 2004). Also, a greater effort must be made to overcome fishermen's reluctance to share information with decision-makers since they believe that this will lead to additional restrictions. Otherwise, it will be difficult for fishermen to rally behind the current conservation measures. Furthermore, strong compliance will require that conservation measures be perceived as meaningful and useful (Kuperan and Sutinen, 1998; Raakjaer Nielsen and Mathiesen, 2003). While it will be impossible to placate many of the fishermen's concerns, engaging them in a meaningful dialogue about the need and expectations of existing regulations will likely enhance legitimacy, acceptance, and compliance with the current conservation measures.

Acknowledgments

We would like to express our gratitude to all the fishermen who kindly shared their time and knowledge of the fishery. Also, we would like to acknowledge the hard work of Jesús León, Héctor Y. López, and Luis A. Rivera, who interviewed the fishermen, and Albaliz Mercado and Lucía T. Vargas, who assisted the port samplers with the interviews, created the database, and collaborated with preparation of the tables and figures. Flavia Tonioli's cartographic assistance and manuscript review is also gratefully acknowledged. Aida Rosario from Puerto Rico's Fisheries Research Laboratory, James R. Waters from the National Oceanic and Atmospheric Administration (NOAA), Graciela García-Moliner from the Caribbean Fishery Management Council (CFMC), and Manuel Valdés-Pizzini from the University of Puerto Rico provided insightful comments on the manuscript. Finally, we would like to thank the administrative support of María de los Angeles Irizarry from the CFMC. Funding from NOAA's Coral Reef Conservation Program and Puerto Rico's Department of Natural and Environmental Resources (DNER) supported this research project.

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Offshore Migratory Corridors and Aerial Photogrammetric Body Length Comparisons of Southbound Gray Whales, *Eschrichtius robustus*, in the Southern California Bight, 1988–1990

JAMES L. SUMICH and IVAN T. SHOW

Introduction

Gray whale, *Eschrichtius robustus*, migratory distribution encompasses coastal waters in the eastern North Pacific Ocean from the Chukchi Sea in the north (Rugh and Fraker, 1981; Miller et al., 1985) to the periphery of the Gulf of California (Findley and Vidal, 2002). Within this geographical range, gray whales accomplish one of the most extensive annual migrations of any mammal. This 15,000–20,000 km migration covers 50° of latitude and links the summer feeding areas in the Bering and Chukchi Seas with the warmer courting, calving, and assembling grounds along subtropical coastlines of Baja California in winter (Gilmore, 1960; Rice and Wolman, 1971; Sumich, 1986).

The route and timing of the migration of California gray whales were described in general terms by Gilmore (1960) for the southern part of the migration and by Pike (1962) for the northern part, although they both lacked sufficient empirical data to clarify year-to-year or age- and sex-related variations in migratory timing. The general picture of migratory timing was substantially improved by the detailed set of morphometric data obtained from 317 whales collected under Special Scientific Permits issued to the U.S. Bureau of Commercial Fisheries between 1959 and 1969 (Rice and Wolman, 1971). Both south- and north-bound whales were sampled between December 1 and April 10 off the central California coast (lat. 37.5° to 38.0°N).

Shore-based studies of migratory patterns have been conducted at Unimak Pass, Alaska (lat. 55°N) (Rugh, 1984); Newport, Oregon (lat. 45°N) (Herzing and Mate, 1984); California (lat. 37°N) (Reilly et al., 1983); (lat. 36°N) (Poole, 1984); and Laguna San Ignacio (lat. 28°N) (Jones and Swartz, 1984). The results were summarised by Reilly (1984) and Rugh, et al. (2001). Collectively, these studies demonstrate that the migration is best described as multiple annual cycles which exhibit considerable temporal overlap in the same geographic range (Sumich, 1986).

Through most of their migration, gray whales remain in shallow coastal waters, almost always within 10 km of shore (Rice and Wolman, 1971; Reilly et al., 1983; Braham, 1984; Herzing and Mate, 1984; Poole, 1984). However, in the California Bight (lat. 32.5–34.5°N: Fig. 1) with its several large islands extending as much as 100 km south and west of the mainland coast, alternative island-hopping migratory routes are used by gray whales. Rice (1965) and Gilmore[1] reported a few incidental sightings of gray whales as far west as San Clemente Island, but both assumed that such offshore occurrences did not reflect major migratory pathways and that, in the bight, most gray whales continued the nearshore migratory behaviour typical of coastal areas farther north.

Later boat-based surveys west of San Diego by Rice and Wolman (1971) generated estimates of a higher percentage (59%) of southbound whales further than 9.3 km west of the mainland shore. It is doubtful that these estimates ac-

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ABSTRACT—Through most of their annual migration, gray whales, Eschrichtius robustus, *remain within 10 km of shore, but in the Southern California Bight many individuals migrate much farther from shore. This paper summarizes aerial survey and photogrammetric efforts to determine body lengths and temporal and spatial distributions of migratory gray whales in the southern portion of the Southern California Bight. Aerial surveys were flown along 13 east–west transects between lat. 32°35′N and 33°30′N during the southbound gray whale migratory seasons of 1988–90 in the Southern California Bight. Photogrammetry was used to obtain body length estimates of animals during some of the surveys. A total of 1,878 whales in 675 groups were sighted along 25,440 km of transect distance flown and 217 body lengths were measured. Using position and heading data, three major migratory pathways or corridors in the southern portion of the bight are defined. Those migrating offshore were split almost evenly between two corridors along the west sides of Santa Catalina and San Clemente Islands. These corridors converge on the mainland coast between San Diego and the United States–Mexico border. No whales larger than 11.5 m were photographed within 30 km of the mainland coast, suggesting that smaller, and presumably younger, whales use the coastal migratory corridor through the California Bight.*

[1]Gilmore, R. San Diego Museum of Natural History, San Diego, Calif., 1979, personal commun.

curately reflect actual distributions of southbound whales because they were calculated using an assumed continuous distribution of whales across an offshore migratory front nearly 200 km wide. Additionally, these surveys were made about 2 weeks after the peak of the migration and may not have included a representative sample of all age groups and sexes.

Results of previous aerial surveys of gray whales in the California Bight indicate that a substantial, but undefined, portion of the population migrates south well offshore at least to the United States–Mexico border. Leatherwood (1974) reported approximately equal encounter rates with gray whales 80–160 km offshore as for 0–80 km offshore. No adjustment was reported for distances from island shorelines or for varying survey effort through the migratory season. Between 1980 and 1983, monthly flights made over much of the California Bight (Dohl et al.[2]) indicated that gray whales migrated throughout the bight, with about 24% using a mainland coastal migratory route. In a study in the Santa Barbara Channel in 1980–81, Leatherwood[3] noted that south-bound gray whales passed the west and east sides of San Miguel Island in approximately even numbers. Their study did not extend to the southern portion of the bight. Incidental sightings of gray whales were noted during aerial surveys of portions of the bight made during 1980–85 (Oliver and Jackson[4]) to investigate abundance of pinnipeds and small odontocetes and most gray whale sightings occurred in the vicinity of Santa Catalina Island. Limited aerial surveys for south-bound gray whales in the northern Channel Islands were conducted in 1986 (Jones and Swartz[5]), but these surveys did not extend into the southern half of the bight. Anecdotal reports by whalewatching boat operators south of Los Angeles (e.g. H. Helling[6]) also suggest a substantial decline during the 1980's in the numbers and group sizes of southbound gray whales accessible to half-day whalewatching boats migrating through nearshore mainland coastal waters.

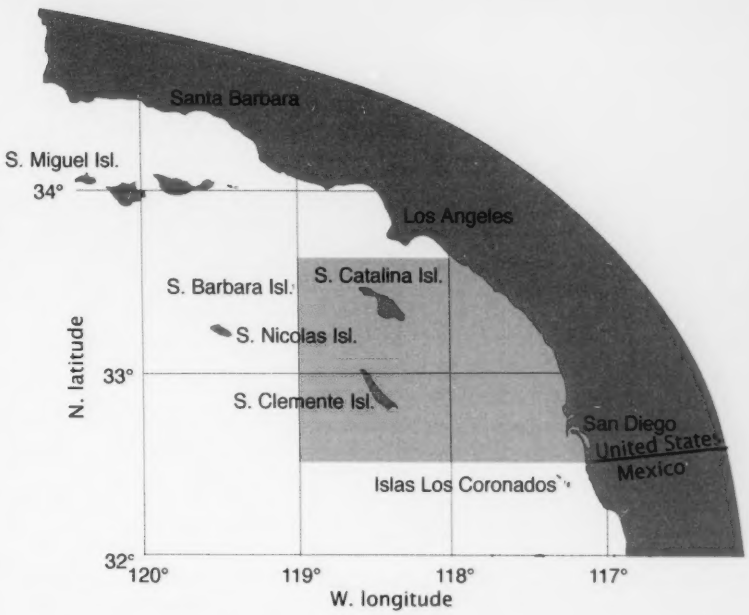

Figure 1.—The California Bight showing major geographic features and islands. Study area is shaded.

This paper reports on results of three years (1988–90) of aerial surveys of southbound gray whales in the southern portion of the California Bight. The purpose was to determine the spatial and temporal distribution of migratory gray whales in the southern portion of the California Bight. A particular emphasis of this study was to detect and define migratory corridors and to compare the numbers, timing, and body size distributions of southbound gray whales migrating near the mainland coast with those of animals migrating near Santa Catalina and San Clemente Islands, located about 40 and 80 km, respectively, west of the southern California coastline.

Methods

Aerial Surveys

Aerial transects were flown during the southbound gray whale migratory seasons of 1987–88 through 1989–90 (referred to here as 1988, 1989, and 1990 seasons) over much of the southern portion of the California Bight (Fig. 1). High-wing, single-engine aircraft (i.e. Cessna[7] 172 or 182L) were

[2]Dohl, T. P., R. C. Guess, M. L. Duman, and R. C. Helm. 1984. Cetaceans of central and northern California, 1980–1983: Status, abundance, and distribution. Prep. for Pacific OCS Region, Minerals Management Service. OCS Study MMS 84-0045, 284 p.

[3]Leatherwood, J. S. Hubbs-Sea World Research Institute, San Diego, Calif., 1979, personal commun.

[4]Oliver, C. W., and T. D. Jackson. 1987. Occurrence and distribution of marine mammals at sea from aerial surveys conducted along the U.S. west coast between December 15, 1980 and December 17, 1985. U. S. Dep. Commer., NOAA, NMFS, SWFC Admin. Rep. LJ-87-19, 189 p.

[5]Jones, M. L., and S. L. Swartz. 1987. Radiotelemetric study and aerial census of gray whales during their southward migration in the Channel Islands National Marine Sanctuary, January 1986. *In* Final Report to National Marine Mammal Laboratory. NMFS, Seattle, p. 97. Prep. for U.S. Dep. Commer. NOAA Sanctuary Program, No. 50-ABNF-6-00067.

[6]Helling, H. San Diego, Calif., 1990, personal commun.

[7]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

used with an observer on each side and a data recorder in the co-pilot position. Preferred flight altitude was 1,000 ft (305 m), but other altitudes were used when dictated by military, air traffic, or weather restrictions. Time, number of animals, Loran C position and compass heading, barometric altimeter reading, sea state, visibility, and behavioral notes for each sighting were recorded manually. Survey efforts were discontinued when visibility declined to less than 10 km or sea surface conditions exceeded Beaufort 3.

Survey effort for the 1988 and 1989 migratory seasons involved several flights per week from early December to late January or early February. In 1990, surveys began in early January and continued to 20 February to include the early portion of the phase A northbound migration (Poole, 1984). Thirteen equally spaced east–west transects 5′ of latitude apart were included. The transects lay between lat. 32°35′ and lat. 33°30′N. Each transect extended from the mainland coast westward to long. 119°W. Within the constraints necessary to avoid resighting the same whales, the order and spacing in which the transects were flown was randomized, although subsequent surveys of each transect was started from the same point. At least two transects were flown on each day, one westbound and one eastbound. Observations were continued on the N–S segments between transect legs.

The study area was divided into approximately 240 discrete 5′ lat. by 5′ long. blocks, and the number of kilometers flown in each grid block was determined. The map position of each whale group sighted was plotted and its heading was extended as a 7 km long line of travel, equivalent to approximately one hour of migratory travel time, to indicate relative density distribution of whales across the bight and to delineate migratory pathways within the bight.

Photogrammetry

On 10, 14, and 18 January 1989 and on 8, 9, and 12 January 1990, the aerial surveys north of 33°45′ were combined with photogrammetry (Perryman and Lynn, 2002) to obtain estimates of body lengths. Vertical aerial photographs were taken through a camera port installed in the side cargo hatch of the Cessna 182L. When animals surfaced to blow, photographs were taken with a Pentax 60×45 mm still camera equipped with a motor drive and vertical bubble level and a calibrated 208 mm lens. The camera was hand-held using a shutter speed of 1/1000 sec to reduce vibration and motion blur. Time, Loran C position, and barometric altimeter readings for each film frame were recorded manually. The camera-aircraft altimeter system was calibrated by photographing the 14.2 m wide west end of the Scripps Institution of Oceanography pier (corrected for its height of 10.1 m above mean lower low tide level). As the maximum vertical range of local tides at the shoreline is less than 1% of our flight altitude and diminishes in deeper water, no corrections for tidal variations were made.

Whale images were projected from the film negatives on a 23× magnifier calibrated with a microscope stage micrometer, and the magnified image was measured to the nearest millimeter (equivalent to about 1% of adult body length). Body length was measured only if both the fluke notch and rostrum tip were clearly visible. These film image body lengths were converted to actual body length (L) values with:

$$L, m = (\text{altitude}, m) \times (\text{length of film image}, mm)/(\text{lens focal length}, mm)$$

Table 1.—Summary of survey flight results.

Distance Year	No. of flown (km)	No. of surveys	No. of sights	No. of whales	Mean group size	No. of sights/survey	whales/ 100 km flown
1987–88	7,422	25	231	642	2.78	9.2	8.6
1988–89	11,597	34	356	1,007	2.83	10.5	8.7
1990	6,421	19	88	229	2.60	4.6	3.6

Table 2.—Means and standard deviations of nearshore and offshore group sizes of gray whales in the California Bight.

Area	No. of groups	Mean	s.d.
Nearshore	143	2.51	1.14
Offshore	532	2.89	2.17
Combined	675	2.79	2.12

Table 3.—Summary of photogrammetric effort, sample size of measured lengths, and mean and standard deviations of lengths for 1989 and 1990.

Year	Distance flown (km)	No. of film frames	No. of whales measured	L(m) Mean	L(m) s.d.
1898	733	92	154	11.1	0.8
1990	527	48	60	11.3	0.9

Results

Aerial Surveys

The survey effort is summarized by year in Table 1. A total of 1,878 southbound whales in 675 groups were sighted along 25,440 km of transect distance flown. The distribution of survey effort, in km flown for each year, is shown in 5′×5′ grids in Figure 2. The positions and headings of each whale group sighted are shown by year in Figure 3. Three principal migratory corridors are apparent, an inshore corridor near the mainland coast and two farther offshore associated with the west sides of Santa Catalina and San Clemente Islands.

Temporal changes in sighting rates (whales/km) for each of the survey years are summarized in Table 1 and shown in Figure 4. Sharp mid January peaks are obvious for 1988 and 1989, with a broader, ill-defined January peak in 1990.

There were no significant group size differences for different survey years (ANOVA $F = 1.117$, $p = 0.33$). In Table 2, group sizes of whales migrating within 30 km of the mainland are compared with those migrating farther offshore. Group sizes in the offshore migratory paths were more variable and were slightly, but significantly, larger than those near shore ($t = 1.647$, $p = 0.04$).

Photogrammetry

For 5 of the 6 photogrammetric surveys, altimeter calibration correction factors were obtained (mean = 1.021,

CV = 4.2%) and applied. The mean correction factor was applied to whale images obtained on the sixth, uncalibrated flight.

Table 3 summarizes the photogrammetric effort and the number of images of sufficient quality for length determinations. The 1989 images included a 4.0–4.5 m long neonate and another 9.5–10.0 m animal with missing flukes. Both are excluded from further analysis, as were two neonates (L = 4.0–4.5 m) photographed in 1990.

Frequency distributions of body lengths for both years are shown in Figure 5. Calculated lengths ranged from 8.4 to 13.2 m (mean = 11.2 m) in 1989 and from 9.7 to 12.5 m (mean=10.9 m) in 1990. Mean body lengths differed only slightly between 1989 and 1990 ($t = 1.97, p = 0.045$). Comparisons of body length with date are not presented, as all photogrammetric surveys were conducted within short time spans; 8 days for 1989 and 4 days for 1990.

Body lengths as functions of distance offshore are shown in Figure 6. No whales longer than 11.5 m were photographed within 30 km of the mainland, and the 2-year combined overall distribution of these nearshore body lengths was significantly different than those farther offshore (K/S max. diff = 3.52, p = 0.027).

Discussion

Gray whales observed migrating south through the bight exhibited similar year-to-year patterns of positions and headings during this study (Fig. 3), with the smallest portion of these whales using what Rice (1965) referred to as "the major inshore migration route." The results of this study delineate two additional major corridors, one each along the west side of Santa Catalina Island (40–50 km offshore) and San Clemente Island (80–90 km offshore). We cannot address the question of where the offshore departure from the coastal pathway occurs north of our study area. But, after clearing the southern ends of Santa Catalina and San Clemente Islands, these southbound whales veer southeast to merge with the inshore corridor between La Jolla and the United States–Mexico border, where most whales presumably continue south near the mainland Mexican coast.

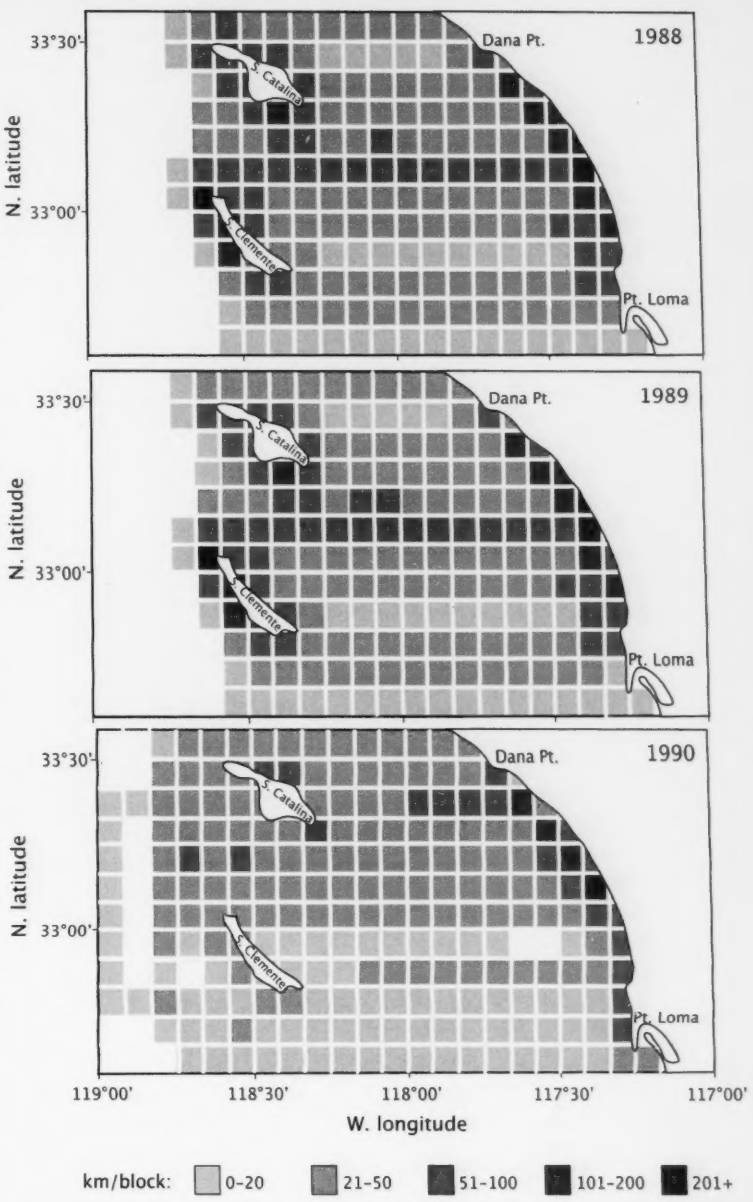

Figure 2.—Cumulative numbers of survey kilometers flown in 5′×5′ blocks (10 km×10 km): 1988–90.

Body length values were compared to those reported by Rice and Wolman (1971) and by Sumich et al. (2001) to estimate maturity. Rice and Wolman (1971) found that the median length at puberty was approximately 11.4 m (11.1 m for males and 11.7 m for fe-

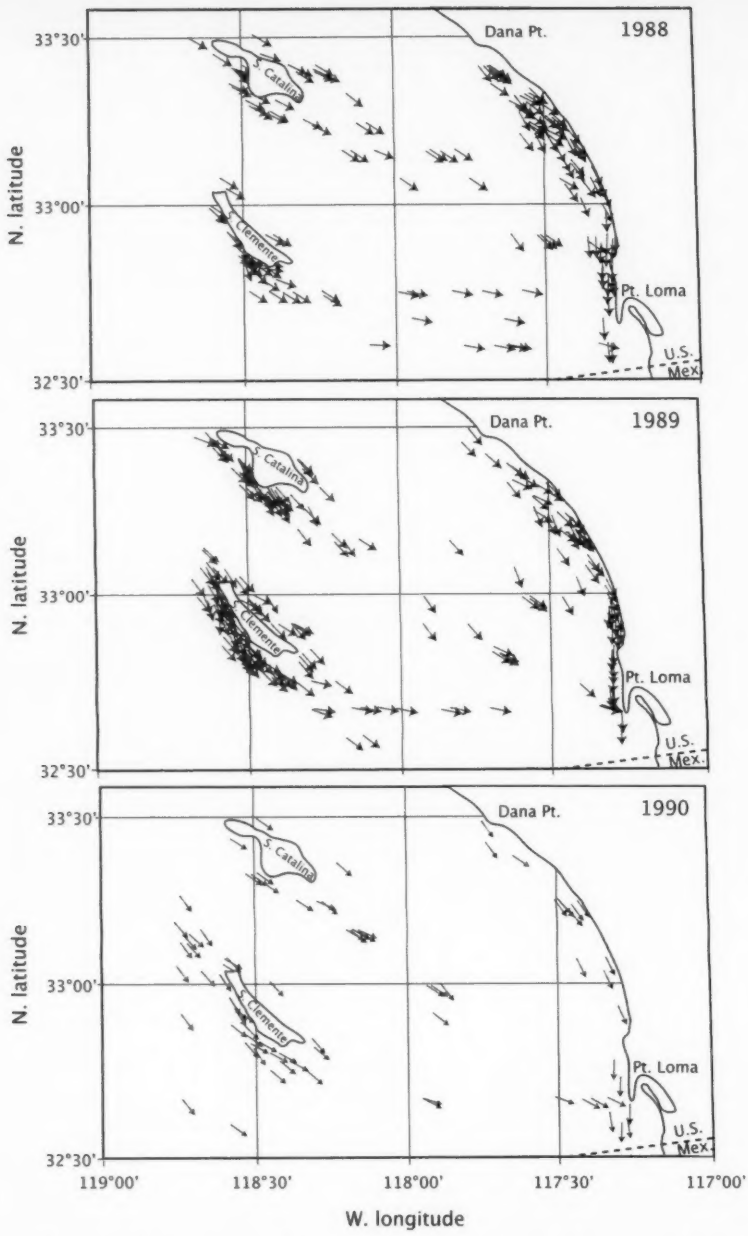

Figure 3.—Positions (bases of arrows) and headings of gray whale groups sighted: 1988–90.

males). All whales larger than 11.5 m were photographed only at distances greater than 30 km from the mainland coast, while smaller whales were photographed in all three migratory corridors.

Our results suggest an offshore preference by larger, presumably older whales, leaving fewer and apparently younger whales to use the mainland corridor through the California Bight. These data also indicate an almost

complete absence throughout the bight of whales with body lengths expected for year-old animals (8–8.5 m; Sumich et al., 2001) and only slightly more apparent 2-year-old animals (9–10 m). Our result may underestimate their relative abundance, as these small whales typically swim alone, likely making them more difficult to detect. However, to avoid underestimating the total size of this population, future shore-based census efforts must determine if representative numbers of these young age classes do indeed migrate south past counting stations.

The migratory corridors shown in Figure 4 have been both consistent and persistent during the 3 years of this study. Those migrating offshore were split between the Santa Catalina and San Clemente corridors, with substantial year-to-year variability. This inter-annual variability in the numbers of whales using each corridor could lead to large variations in the results of single shore-based census efforts elsewhere in the bight.

Within the past 100,000 years, gray whales must have ranged widely in coastal waters of both the North Pacific and North Atlantic Oceans. During the Last Glacial Maximum (LGM, 18,000 years B.P.), sea level was about 150 m below its present stand (Imbrie et al., 1983). With sea level lower and all the islands of the bight substantially larger, migrating gray whales most likely skirted the west sides of these islands and avoided the coastal mainland of the bight until they were clear of Santa Catalina and San Clemente Island.

In general terms, the two offshore migratory corridors described in this paper reflect the expected migratory pathways for gray whales during the LGM. It is tempting to speculate that these whales currently use the offshore corridors to avoid human-induced changes in environmental conditions within the bight, yet no evidence currently exists to support or to deny such speculation. Rather, the offshore migratory corridors described here may have been used by varying portions of the gray whale population at least since the LGM.

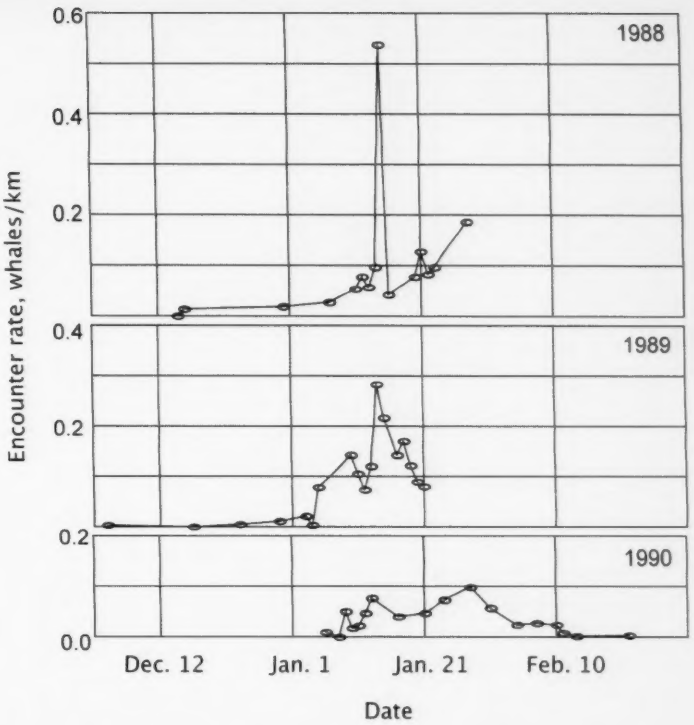

Figure 4.—Temporal changes in encounter rates of whales. When multiple surveys were flown on the same day, the results were combined for single daily values.

Acknowledgments

This work was supported by grants from the U.S. Navy Facilities Engineering Command, San Bruno, Calif. (Contr. N62474-M-0942); Grossmont/Cuyamaca College Foundation; Cetacean Society International; and American Cetacean Society, San Diego Chapter. The manuscript benefitted substantially from the critical reviews of W. Perryman, D. Rugh, L. Hiby, W. Koski, J. Barlow, and an anonymous reviewer.

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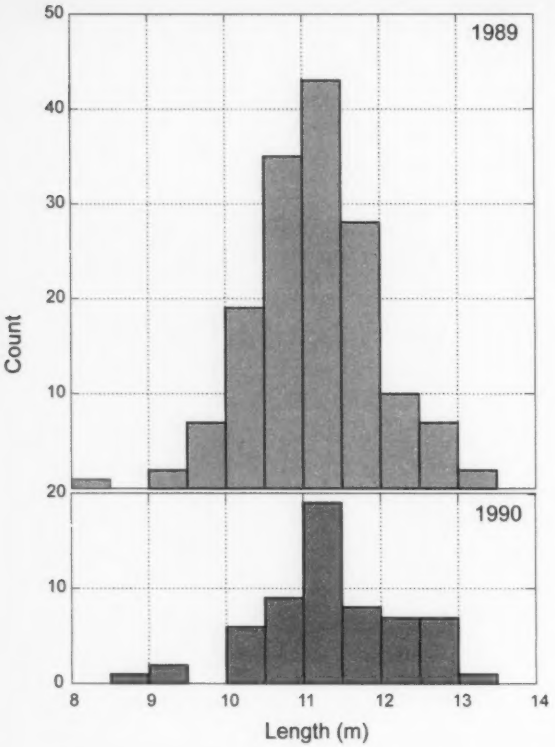

Figure 5.—Frequency distribution of photogrammetrically derived gray whale length classes for 1989 (top) and 1990 (bottom).

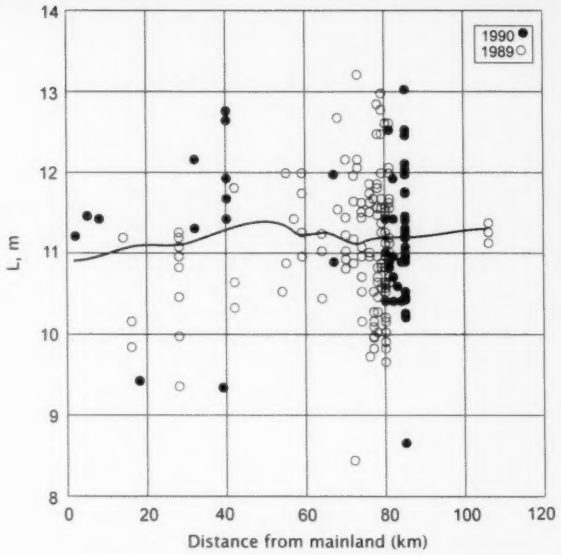

Figure 6.—Distribution of photogrammetrically derived gray whale lengths with distance west of the mainland shore, with loess curve fit for both years combined (tension = 66).

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Manuscripts must be typed double-spaced throughout and submitted with two duplicate copies. The complete manuscript normally includes a title page, a short abstract, text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

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Keep titles, headings, subheadings, and the abstract short and clear. Because abstracts are circulated by abstracting agencies, it is important that they represent the research clearly and concisely. Headings within each section must be short, reflect a logical sequence, and follow the rules of multiple subdivision (i.e. there can be no subdivision without at least two items).

Style

The entire text should be intelligible to interdisciplinary readers; therefore, all acronyms, abbreviations, and technical terms should be spelled out the first time they are mentioned. The scientific names of species must be written out the first time they are mentioned; subsequent mention of scientific names may be abbreviated. Follow the U.S. Government Printing Office Style Manual (1984 ed.) and the CBE Style Manual (5th ed.) for editorial style, and the most current issue of the American Fisheries Society's Common and Scientific Names of Fishes from the United States and Canada for fish nomenclature. Only journal titles, scientific names (genera and species), and vessel names should be italicized. Dates should be written as follows: 11 Nov. 1991. Measurements should be expressed in metric units, e.g. metric tons as t; other equivalent units may also be listed in parenthesis. Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. The numeral one (1) should be typed as a one, not as a lowercase el (l). Write out the numbers zero through nine unless they form part of measurement units (e.g. nine fish but 9 mm).

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